

# Pilot training review – interim report: literature review

CAP 1581b



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# Preface

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This independent research, initiated and funded by the CAA, and part of the CAA's strategic approach to improving safety, reviews UK pilot training in the wider international context. Against a background of increasingly highly automated aircraft, with air travel as a major UK industry with a consumer expectation of the highest safety standards, it is essential that pilots receive effective, evidence-based training that keeps pace with technological, operational and organisational change. This report, together with associated reports below, detail current research directions, current training issues and opportunities. We will explore with the aviation industry how potential safety improvements may be achieved to maximise the benefits of this study.

## **Related publications**

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- [CAP 1581 – Recommendations and Conclusions](#)
- [CAP 1581a – Gap Analysis](#)
- [CAP 1581c – Interview Study](#)



**Pilot Training Review**  
**Interim Report: Literature Review**

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## SUMMARY

Following a number of air accidents where pilot training has been cited as a contributory factor, the effectiveness of pilot training has come under increased scrutiny. In response, the aviation community has been exploring approaches to address problem areas, and the CAA was keen to understand the extent of such activities, their impact, and any remaining issues not being addressed. To this end, the CAA commissioned this project to “review of recent training studies and activities and potential improvements in order to inform policy on taking the matter forward internationally.” (CAA Research Specification for Project 2217, 2014).

The project is divided into two main information collection phases:

1. Literature review
2. Interviews with aviation community stakeholders.

From these, a Gap Analysis will explore the shortfalls and any residual risk, with the results and emerging recommendations from this being presented to and discussed with stakeholders from the aviation community through an Industry Workshop. The overall project output will be a set of recommendations for interventions and/or further developments to improve training-related safety outcomes for UK aviation.

This document describes the findings of a review of recent training literature on pilot training and associated topics. The objective of the literature review is: *to establish the ‘state of the art’ in pilot training*, including to identify the current and latest training techniques, design philosophies and recommended content, including the results of training effectiveness evaluations, skill fade studies and consideration of issues around instructor training.

The key findings from the study are:

- ▶ The literature identifies a wide range of ‘state-of-the-art’ training activities; however the extent to which these are implemented in the aviation training community is not known.
- ▶ There is an increasing use of Competence-Based Approaches in training, supporting trainee resilience, as it becomes impossible to train for every eventuality possible in a modern cockpit.
- ▶ Training that provides pilots with resilient skills enables the pilot to be adaptive to a wide catalogue of situations.
- ▶ To achieve implementation of the state-of-the-art in operational training, it is crucial that there are organisational pathways that bridge the gap between research and the development of training programmes and the day to day training of pilots.

Additionally, the literature review revealed key gaps in knowledge and available information, including:

- ▶ Clearly defined, detailed competency frameworks for pilot Knowledge Skills and Attitudes to be addressed in the competence-based training ;
- ▶ Guidance on integration of technical and non-technical training from the early stage;
- ▶ Techniques for stress management training, including introducing more realistic stress to training sessions for stress inoculation;
- ▶ Evaluation of the effectiveness of training courses and programmes along the pilot career pathway.

The findings will be used to inform the design of questions for the Interview Study and as an input to the Gap Analysis.

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## 1. INTRODUCTION

### 1.1 PURPOSE

This document is the first interim report from CAA project 2217: Pilot Training Review. It describes the findings of a review of recent training (research and development) literature on pilot training and associated topics. The literature review was conducted over Spring 2015. Later reports in the project will describe how air operators and training establishments deliver training against current regulatory requirements and will detail the gaps between this and the state-of-the-art.

### 1.2 PROJECT BACKGROUND AND AIMS

Following a number of air accidents where pilot training has been cited as a contributory factor, the effectiveness of pilot training has come under increased scrutiny. In response, the aviation community has been exploring approaches to address problem areas, and the CAA was keen to understand the extent of such activities, their impact, and any remaining issues not being addressed. To this end, the CAA commissioned this project to:

“Review of recent training studies and activities and potential improvements in order to inform policy on taking the matter forward internationally.” (CAA Research Specification, July 2014).

The project is divided into two main information collection phases: a Literature Review and Interviews with aviation community stakeholders. From these, a Gap Analysis will explore shortfalls and any residual risk, and the results and emerging recommendations from this will be presented for discussion with stakeholders from the aviation community. The overall project output will be a set of recommendations for interventions and/or further developments to improve training-related safety outcomes for UK aviation.

The project scope considers the breadth of civil commercial aviation including fixed- and rotary-wing aircraft, different operator types and training organisations, and also explores future changes in military aviation that could influence the pilot training pipeline.

### 1.3 LITERATURE REVIEW

#### 1.3.1 Objectives

The objective of this literature review is: *to establish the ‘state of the art’ in pilot training.*

More specifically, the purpose was to review aviation human factors and training literature and available material published through various national and international aviation organisations to identify the current and latest training techniques, design philosophies and recommended content, including the results of training effectiveness evaluations, skill fade studies and consideration of issues around instructor training.

The output of the literature review will be used to inform the design of questions for the Interview Study (Task 2) and to feed into the Gap Analysis (Task 3).

#### 1.3.2 Approach

A standard literature review methodology was used:

- ▶ Identify search terms and information sources;
- ▶ Conduct the searches and down-select relevant documents;
- ▶ Review the material and extract pertinent issues;
- ▶ Collate findings and organise into report.

The initial search terms used in this project covered a wide range of issues associated with pilot performance and aviation safety in combination with 'Pilot Training'. These included: automation management, monitoring, crew resource management (CRM), and non technical skills, meta-cognitive competences, adaptability, crisis management including managing the 'startle factor', impact of changes in training pathway and reduced time to command. Additional searches were also made for: airline selection, skill retention, instructor training, training design and training evaluation. The main search considered material up to six years old but where nothing was available this was extended further back by a few years where required. No research was considered from more than 10 years ago because of the requirement to look at recent developments.

The main search focussed on: human factors and aviation psychology journals and publications, such as the proceedings from Human Factors and Ergonomics Society Annual Meetings and the International Symposium on Aviation Psychology. The search also included sources of grey literature, e.g. CAA, FAA, European Aviation Safety Agency (EASA), IATA, International Civil Aviation Organisation (ICAO) and the Royal Aeronautical Society (RAeS). However, not all of these sources yielded 'state-of-the-art' information. For example, no EASA documents were identified beyond the formal regulations and guidance. Additionally, a number of aviation researchers/training developers were also contacted directly to obtain information on their latest research.

The literature review did not include collecting materials from individual air operators, as these experiences will be collected through the Interview Study. Nor was the regulatory or formal guidance material on training course content, methods and evaluation, etc. reviewed, as this material is well known and amounts to the current state of activity rather than latest developments.

It became apparent that the use of detailed search terms was not entirely useful, and so the search phrases used were broadened to encapsulate more general topics on pilot training and modern aviation. This yielded more information but it became quite difficult to distinguish articles and reports describing training developments and techniques, i.e. 'the solutions', as opposed to the large number of investigations that describe 'the problems'. Numerous studies describe data on pilot performance problems, e.g. startle factor, automation awareness or monitoring skills, and then recommend that training be developed to address these. Unfortunately, they do not specifically provide any information on the design or delivery of that training. The result of this is that while training is frequently mentioned in a wide range of documents and reports, the amount of material identified on specific pilot training approaches is relatively small, certainly in terms of recent or emerging developments. Therefore, where apparent gaps exist in the research were identified they have been highlighted.

## 1.4 REPORTS STRUCTURE

The remainder of this report is divided into the following sections:

- ▶ Context: overview of key pilot performance, aviation safety and training issues to provide context for training developments;
- ▶ Training philosophies: brief discussion of development around broader approaches and philosophies in training;
- ▶ Competency-related developments: the main body of the review in terms of latest developments in training delivery, content, media, etc are presented around recognised pilot competencies and discussed;

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- ▶ Other: discussion of a number of other factors that could influence training outcomes;
  - ▶ Conclusions on the State-of-the-art: summary of the key training themes and gaps to take forward to subsequent tasks, and any recommendations for further literature investigation;
  - ▶ References: detailed references and bibliography of material reviewed.

## 2. CONTEXT

### 2.1 INTRODUCTION

This section provides high-level information of the overall context of current aviation training. It is included because training developments need to respond to issues from across the whole aviation system. This may be the need to strengthen key pilot skills because of safety concerns or to improve efficiency due to increasing demand. The main discussion is divided into three areas: high level information about the pilot training journey; pilot-related safety challenges, i.e. what are the current areas for concern; and some broader considerations mainly around the increasing growth of aviation worldwide. A final section lists some potential areas that might be expected to emerge from the literature to address some of these current and future challenges.

### 2.2 TRAINING JOURNEY

#### 2.2.1 Traditional *Ab Initio* Training

The traditional *ab initio* training path focuses on the trainee's progression through clearly defined training phases. Each phase addresses specific contents and progression through the phases requires the trainee to be assessed as meeting a measurable standard. As a result of the structured, incremental nature of the training programme and the fixed assessment 'gates', the initial entry standards for training schools may be variable. Some training organisations will fix very high entry requirements. Others will adopt a more open selection approach, which theoretically should not be an issue because of the common assessment standard.

The first element of *ab initio* training is basic training. This is the acquisition of a Private Pilot's Licence (PPL). Following on from this, training focuses on hour - building, theoretical ground school training and advanced flight training (using both aircraft and simulators). Having achieved a frozen Airline Transport Pilot Licence (ATPL), trainees are then eligible to work as a First Officer with an airline once specific aircraft type training; when a requisite number of flying hours have been completed the ATPL is unfrozen.

There are two main pathways for trainees to choose between: integrated courses are full time (lasting 16 to 20 months) and provide the complete path, incorporating *ab initio* and type rating in a single approved training organisation; Modular courses offer more flexibility, with trainees gaining their PPL and further accreditations over a longer and flexible time period and with the opportunity to learn different modules from various training organisations.

#### 2.2.2 Type Rating Training

Type rating training follows on from *ab initio* training, and provides trainees with the skills required to operate a specific type aircraft for a specific operator. This incorporates a technical ground school course, simulator training and aircraft base training (landings). Manual flying skills learnt in basic training are built upon with the development of automation flying skills, systems management skills (such as the use of flight management systems) and familiarisation with standard operational procedures.

Additional training can be appropriate prior to starting type rate training, to support trainee pilots' transition to a specific aircraft type. Multi Crew Cooperation (MCC) courses train single seat pilots in the team skills necessary for the safe operation of complex, multi crew, jet aircraft; and Jet Oriented Courses (JOC) support trainee pilots transitioning from flying propeller aircraft to jet engine aircraft, improving jet handling skills and incorporating some standard operating procedures.

### 2.2.3 MPL Training

The Multi-crew Pilot License (MPL) was introduced by ICAO in 2006 as an alternative to the traditional *ab initio* training route. The MPL approach trains participants specifically to join a known air operator flying an already identified aircraft type. Courses take a competency approach with trainees meeting specified performance criteria. Trainee screening at the selection stage is comprehensive because the trainees have been selected by the airlines for attend the training for their operations (for an overview of Pilot Screening, see Section 5.1). Following theoretical ground school training, Phase One focuses on basic flying training. In Phase Two, Three and Four, simulators are used to build type specific flight skills and multi-crew coordination. The training is operations-oriented and incorporates airline specific standard operating procedures (SOPs) from an early stage in the training whereas in MCC crew resource management skills and SOPs are taught as an additional. Each MPL course is bespoke, fitting the specific operator's needs.

### 2.2.4 Recurrent Training

The minimum frequency of recurrent training and checking is mandated at a high level by the regulation, e.g. yearly flight simulator aircraft system failure training to three year rolling for CRM. Delivery under this is defined by the operators and is type dependent. Recurrent training is required to: enhance aviation knowledge and skills (e.g. simulation of emergency or abnormal situations); train new equipment, regulations or procedures; and ensure a level of proficiency has been maintained. This normally incorporates both ground school training and Line-Oriented Flight Training (LOFT) in a flight simulator. This recurrent training should also cover non-technical skills for Crew Resource Management (CRM) in normal and emergency operations.

The introduction of Evidence-Based Training (EBT; IATA, 2013) over recent years is seeking to encourage air operators to base their on-going training on the specific requirements and issues associated with their operations.

### 2.2.5 Command Training

Command training programmes are defined by each air operator according to their operations and requirements. The regulator then certifies these courses to ensure that they meet high level requirements of what commanders 'shall' be able to do. The process for getting to the promotion point is again defined by internal processes, which have been approved by the regulatory Flight Operations Inspector. As such there is no standardisation across the industry and the time to reach a command post takes significantly different amounts of time, depending on the organisation. In some airlines this can be after 4-5 years as a First Officer/Co-pilot and in other airlines it can be as much as 15-18 years to reach Captain.

In addition to formal command courses, some airlines offer Command Mentorship programmes to help new commanders in post. A number of Command Preparation Courses are also available from independent training suppliers.

### 2.2.6 Conversion Training

Experienced pilots will undergo a reduced form of type rating training as part of a conversion course if they change aircraft types. The scope of this is likely to be dependent on the specific transition. For example, changing between two aircraft from the same manufacturer is like to create less of a training burden than changing between aircraft from completely different manufacturers, with different underpinning design philosophies.

### 2.2.7 Instructor Training

Current international guidance recommends that instructors hold or have held the equivalent qualification for the level being taught. They also may have gone through a selection process to

assess their competence, motivation and disposition (this is required for MPL and EBT) (IATA, 2013). Annual refresher training is also recommended by the IATA report (2013).

### 2.2.8 Helicopter Training

Helicopter training follows a similar route to the *ab initio* and type rating training described for fixed-wing aircraft (sections 2.21-2.24) but excluding the MPL specific approach.

A Commercial Pilots Licence (Helicopter) (CPL(H)) can be achieved through modular or integrated courses, both of which incorporate flight time experience and theoretical learning to gain the required level of knowledge and experience. Following this, trainees undertake a 35 hour Commercial Flying Course and a pilot 'skill test' to gain their CPL(H). The trainee can then progress to achieve an Airline Transport Pilots Licence (ATPL(H)) through gaining flight hours, instrument rating, experience of multi-crew helicopters and theoretical training.

Type Rating Training Organisations conduct 'post qualification' conversion training in respect of specified types and classes of helicopter. Recurrent training is as with airline requirements.

## 2.3 PILOT RELATED SAFETY CHALLENGES

### 2.3.1 Current Issues

Discussed below are the safety issues outlined across the literature that are most relevant to pilot training.

### 2.3.2 Loss of Control

Loss of Control In-flight (LOC-I) events resulted in the highest number of fatal events over the past decade (Significant Seven, CAA 2011). LOC-I events occur when the plane exceeds the normal flight envelope and subsequent crew action (or inaction) leads to loss of control of the aircraft. During LOC-I the crew needs to identify the true state of the aircraft, to understand the factors that are contributing to the incident and to take the appropriate action in light of these. This can require taking over with complete manual flight or adjusting the level of automation to use flight controls in a lower mode. The skills required for this are defined as Upset Recovery and training in this is now a regulatory requirement. . These events are unexpected, and often pilots struggle to define all of the contributing factors, leading to inappropriate recovery action. Issues of reducing levels of manual flying skill are also a concern here.

### 2.3.3 Rejected Landing

Go-around, due to rejected landings, is a challenging manoeuvre. Go-arounds may be ordered by air traffic control or determined by the flight crew in light of flight conditions, such as an unstable approach. The industry has identified them as a safety issue because they are often either poorly executed or a decision is made to continue the landing when a go-around should be performed.

### 2.3.4 Use of Automation

Over- reliance on automation can create an 'out of the loop performance problem' (Clegg et al., 2010). The 'out of the loop performance problem' is a consequence of the use of automation, where operators of automated systems struggle to take back control in the case of automation failure, as they are outside of 'the loop' due to their role as observer during normal operation. In PARC and CAST's<sup>1</sup> (2013) work group accident analysis, pilots were identified as being 'out of the control loop' in over 50% of accidents. In these situations the pilots have been found typically to over-delegate authority to the automated system control. This results in reduced

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<sup>1</sup> Performance-based operations Aviation Rulemaking Committee (PARC) and Commercial Aviation Safety Team (CAST) Flight Deck Automation Working Group.

situational awareness and reduces the pilot's ability to anticipate aircraft behaviour, making it challenging to take control and manage unexpected events. Automation dependency is of equal concern in helicopter operators, with British Airline Pilots' Association (BALPA) raising their concerns that new helicopter pilots may rely too heavily on automated systems (CAA, 2014).

### **2.3.5 Mode Management / Awareness**

Mode management refers to a pilot's ability to understand the character and consequence of autoflight modes. This includes choice of modes, disengaging and transitioning between modes and being aware of and anticipating automatic mode transitions made by the autoflight system (Hutchins, 2007). The issue of pilots being caught unaware by the automation or not understanding what it is doing is widely reported, particularly in the helicopter environment. Concerns regarding pilot mode awareness were raised in the FAA Human Factors Team report in 1996, which suggested training should better address understanding of automation and mode awareness. However, issues with mode management are still being identified as a concern nearly 20 years later.

### **2.3.6 Startle**

Previously, in older aircraft pilots would expect engine and systems failures, now as accidents and faults do not occur regularly, pilots do not expect these problems and instead are used to a highly reliable system. As a result, pilots are often surprised by unexpected events and lack readily accessible mental action plans. Startle occurs when the information observed by the flight crew does not correspond with the flight crew's current understanding and expectation of the situation. This can result in startle: a strong physiological, psychological and emotional response, impairing cognitive and motor ability, and even resulting in 'freezing'.

Startle has been identified as a causal factor for loss of control events related to monitoring lapses (CAA, 2013). This report illustrates how low arousal can lead to pilot vulnerability, and how then sudden unexpected stimuli can cause a startle response, which in turn can lead pilots to loss of situational awareness, inappropriate actions and, ultimately, loss of control.

### **2.3.7 Threat and Error Management (TEM) / Crew Resource Management (CRM)**

TEM is based on the fundamental idea that threats and errors, and the management of these, are part of everyday crew operations. Threats exist and are beyond the control of the crew, whereas errors originate from how the crew carries out their duties. For example, threats can be environmental, such as weather conditions; operational, such as time pressures; and equipment or maintenance failures. Examples of errors include communications errors such as misinterpretation of information; procedural errors such as a missed briefing; or handling errors such as mode selection or navigation errors. Whereas CRM emphasises the role of communication and skills in maintaining safety in the cockpit, TEM offers a broader framework for the management of threats, errors and crises and risks to encourage resilience. Within TEM, CRM and other technical and non-technical skills are used to manage the risks of threats and errors. Any breakdown in TEM increases the risk on incident on an aircraft and could result in LOC-I.

## **2.4 BROADER ISSUES**

### **2.4.1 Growth in Air Travel**

There is a rapid growth in air travel, leading to increasing air traffic. Where the aviation industry has traditionally centred on American and European carriers, current growth is mainly seen in developing markets such as Asia. This has an impact upon harmonisation. Much of the previous effort of harmonisation has been within Europe and between Europe and the USA.

For example, harmonizing the operation and maintenance of aircraft to improve interoperability and reduce issues of non-compliance. This will now need to be extended to incorporate other countries. Increasingly air operators will be multi-national organisations and so pilot training and crew procedures will need to become increasingly sensitive to cultural differences.

Despite the growth in capacity in air transport across the world, tolerance of air accidents is going down. Therefore, the levels of safety need to be, and be seen to be, improving all the time. Over the past decades much of this has been accounted for from improved aircraft technology but accidents do still occur, frequently related to the issues identified in section 2.3, and as a result the spotlight on the human in the cockpit is ever growing.

#### **2.4.2 Pilot Supply and Demand**

This growth in the market also creates a greater demand for pilots, placing pressure on training organisations to increase throughput and pilot availability. This increased demand results in the need to broaden the recruitment pool, both locally, increasing the throughput of training, and globally, through training organisations developing pilot training opportunities in other countries. An impact of this is the increasing likelihood that pilots will be working in crews with more diverse backgrounds, either having been trained by different organisations or different countries. An example of this is the increasing number of pilots who will not have English as a first language. Over the past 18 years there has been a significant increase in students choosing to receive flight training outside of their native country (Damos, 2014). This creates a requirement for language proficiency testing and training to be integrated within in pilot training courses. The increasing likelihood of multi-cultural flight crews may place a greater demand on a crew's resource management skills. For example, a crew member working with English as a second language may experience greater cognitive demands when managing an emergency situation, however no available research was identified that explored the requirements and difficulties of crew resource management in these settings.

While the demand for pilots grows, it has been observed that substantially fewer pilots are coming from a military background (Damos, 2014; Caligan, 2012). Military pilots fly high performance aircraft in a variety of different settings. The main difference between civilian and military training is that military pilots are taught to handle the aircraft with confidence throughout the entire flight envelope, including various stalls and spins as well as aerobatics and flying at speed. This manual handling is emphasised throughout training and therefore provides pilots from a military background with greater experience of manual flying skills. A reduction of ex-military pilots in the recruitment pool will lead to fewer pilots with a strong grounding in manual flying skills.

In addition to the change in the pilot training pool, the demand for pilots may also drive a reduction in time until command. Currently the progression from First Officer to Pilot requires extensive flight experience, as the demand for pilots increases the number of First Officers with such a high level of flight hours will reduce.

#### **2.4.3 Instructor Demand**

With the increasing demand for pilots, so comes an increasing demand for instructors. Not only must instructors be identified, they must also be trained and evaluated in order to train and evaluate others. This takes time; also as pilots move through the ranks quicker, in the future instructors could end up with less overall experience to meet the demand.

As aircraft become more complex, the training necessarily must deal with this. So not only must instructors have knowledge and skills associated with training and use of various types of modern simulation devices, they must also keep up to date with the changes in technology and automation. Major variations have been identified in recurrence of instructor training across the



industry. Some training programmes do evaluate instructors regularly, assessing manoeuvres and instructor technique (PARC & CAST, 2013). This is beneficial for instructor development, ensuring consistency and keeping instructors up to date. The concern over instructor standards is so great in some areas that the Offshore Helicopter Review (CAA, 2014) recommends that the (regulatory) requirement for instructor tutor training is reviewed, especially to support type rating instructors' knowledge of aircraft and the operating environment.

All these issues add considerably to the overall training burden in the aviation community and, therefore, as pilot training develops so consideration should also be given to the design of instructor and examiner tasks.

#### 2.4.4 Cost

Cost is a constraining factor when considering training. Commercial aircraft operate with low profit margins, due to pressure to lower the cost of air travel, and operators are required to make ongoing improvements to operate more efficiently. Therefore, there is an organisational interest in reducing training investment. This means that course duration is being reduced, which will have an effect on the amount of material that can be covered (which becomes a problem as the amount of information to be covered goes up as aircraft get more complex) and the time available for practice and consolidation is reduced.

## 2.5 EXPECTANCIES ON THE STATE OF THE ART

Given the ongoing growth in air travel and the international concerns over pilot performance, of which training is one of the key mitigating factors, there is a wide range of developments in philosophy, content, delivery, and assessment that might be expected to characterise the state of the art in pilot training.

A list of possible examples of this would include:

- ▶ Approaches to improve the efficiency of pilot learning;
- ▶ Approaches to improve the effectiveness of training;
- ▶ Optimisation of instructor and examiner selection, training, calibration and certification;
- ▶ Development of specific techniques to address key knowledge, skills and attitudes (KSAs);
- ▶ Exploration of optimal design for training pilots for modern aircraft, including managing skill fade, switching from supervisory control to manual control, etc.;
- ▶ Greater selection for core competence;
- ▶ Clear definition of competencies or KSAs;
- ▶ Results from evaluations of different training philosophies, e.g. EBT and specific training interventions, e.g. TEM training.

This list is presented here to prompt the reader to what might be potentially relevant developments to be found in the literature on aviation training given the current safety and operating contexts.

### 3. LATEST TRAINING PHILOSOPHIES

#### 3.1 EVIDENCE-BASED TRAINING

In recent years, the key direction in training across industries has been towards a competence-based approach. Competence-based training requires learners to demonstrate that they can do a task well enough to be assessed competent in the execution of that task. The focus is on the learner and what they can do at the end of their training, i.e. the output, and not on the input to the training, e.g. course duration. This approach has clear benefits in safety critical domains where it is vital to ensure that trainees can demonstrate the necessary knowledge, skills and attitudes in performance of their tasks in order to complete their training. As such, the approach is gaining traction for pilot training. For example, a competence-based approach is at the core of MPL, where instead of pilots meeting flight hour requirements the training focuses on skill development. MPL uses a systematic training methodology, where the curriculum takes into account the capabilities required in the role and the traits of the trainee population to create clear learning objectives. The other significant example is Evidence-Based Training.

Evidence Based Training (EBT) is a training approach developed by the International Air Transport Association (IATA, 2013). Its aim is for pilots to demonstrate competency in required areas during assessments rather than just successfully achieving a predetermined outcome, such as flying repetitive manoeuvres. As such, it is adopting the newer approaches to training that focus on what people can do, competences, rather than how long they have been doing it. This encourages trainees to demonstrate a higher level of performance, rather than passing with the minimum standard. The training aims to facilitate trainees' development of expertise and resilience to manage line operations and non-normal events. It incorporates technical and non-technical competencies. The documentation includes a set of pilot competencies and behavioural indicators developed by an expert industry working group:

- ▶ Aircraft flight path management, Manual flying skills;
- ▶ Aircraft flight path management, Automation flying skills;
- ▶ Situational awareness;
- ▶ Problem solving and decision making;
- ▶ Workload management;
- ▶ Application of procedures;
- ▶ Communication;
- ▶ Leadership and teamwork.

These are defined using a combination of the knowledge, skills and attitudes (KSAs) required to perform tasks to the prescribed standard. However, the list is effectively a summary of existing definitions of technical tasks and under-pinning non-technical skills, and because of this there is considerable overlap. For example, Aircraft Flight Management, Automation is described as:

*“Controls the aircraft flight path through automation, including appropriate use of flight management system(s) and guidance.” (IATA, 2013, p65)*

But achieving this would be impossible without the use of the identified non-technical competencies (e.g. situation awareness, problem solving and decision making, communication, etc. as listed overleaf). Hence the competencies as described could still result in valuable opportunities to integrate skill areas to be missed.

Only limited information is provided about the different elements of these KSAs. Indeed, In line with the 'risk-based' foundations of EBT, the Implementation Guide recommends that operators should develop their own competency frameworks to tailor the system to their needs. Unfortunately, the guide does not include information on how to conduct a KSA or training needs analysis or to develop a competency framework.

Todd and Thomas (2013) conducted a study which found that typically, trainees flight hours were very similar, reflecting the minimum training hours and the syllabus of the organisation within which they were training; this is not in line with the normal distributions associated with other elements of human performance. Indeed, Todd and Thomas argue that the minimum hours requirement of 150 hours total flight time in Australia is at odds with the competency-based training concept, with pilots who are competent at 150 hours of flight time may well have been competent before. They observed that competency-based training is difficult to implement due to problems in the definition of the competencies, implementation, and assessment. Therefore, aviation regulators tend to base decisions regarding flight training and flight training innovations on existing data and not an ideal view of what should be happening in the aviation training system. This said, the Australian aviation system has used the competency-based training approach for many years, incorporating the training of non-technical skills into its syllabus. Unfortunately, there is limited information about the evaluation of this training technique (Todd and Thomas, 2013).

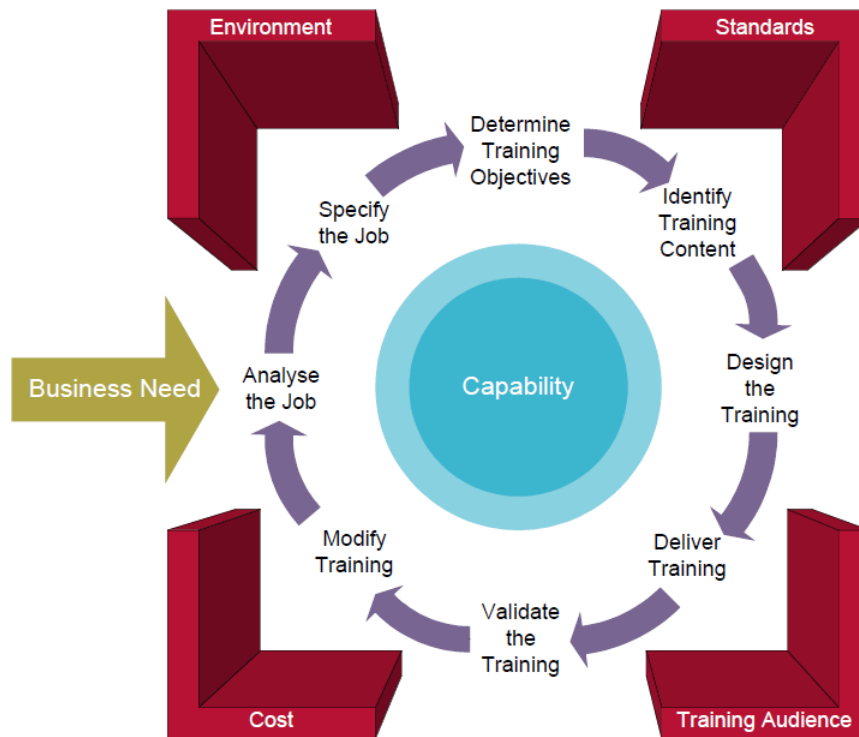
### 3.2 IMPROVED PATHWAY INTEGRATION

As part of the European Airline Training Symposium, Greubel (2014) set out global training challenges including industry growth and experience loss, increasing automation, the need for effective CRM, threat and error management, threats from the growth and complexity of the system. It suggests that current *ab initio* training needs updating. There is a need to incorporate TEM and CRM in all training phases, providing a competency based training course that facilitates the understanding and application of knowledge. There is also a requirement for more rigour in the system, ensuring that trainers have the appropriate KSAs to deliver training, and that their competencies have been assessed and the necessary qualification provided. Additionally, data is needed to support a performance based environment, to assess trends and enable individual and generic feedback.

Barshi (2015) offers a framework for integrated pilot training. He suggests that there may be an opportunity to improve pilot routine training by making it all 'line oriented' so that training reflects the day to day tasks of pilots, integrating the training the skills required. To address this, Barshi developed a 'Comprehensive Line Oriented Flight Training (LOFT)' training approach. This approach addresses the elements of the system that the pilot needs to be familiar with to make strong operational decisions, training students in terms of flight phases rather than detailed subsystem knowledge. Currently, ground school training focuses on engineering aspects and different subsystems, comprehensive LOFT training embeds this knowledge within the skills and procedures required in operational context.

### 3.3 SYSTEMS APPROACH TO TRAINING

A systems approach to training development can be applied across different domains and circumstances. The aim of such an approach is to develop a cost effective training solution, providing a systematic approach to develop training based on training needs and in light of organisational issues. Figure 1 demonstrates the stages of training development, beginning with analysing the job which will identify the KSAs required for the role; this feeds into design, implementation and evaluation.



**Figure 1 Elements of a systems approach to training development**

It is key to realise that the cycle continues to ensure that training continues to address changing KSAs or changing training audience needs, and that evaluation needs to occur at all stages to ensure training is targeted and to provide evidence of training impact. The UK defence community is required to follow a standard set of processes outlined in the Defence Systems Approach to Training (DSAT; MOD, 2012), which provides a quality framework for ensuring the necessary processes are in place to develop appropriate, robust and integrated training solutions are developed.

### 3.4 DIRECTIONS IN TRAINING SCIENCE

Tiley and colleagues (2011) produced a review of the recent concepts, theories and emerging principles for training design to support Tri-Service training on behalf of the UK Defence Science and Technology Laboratory (DSTL). This report highlighted several areas of training design aiming to maximise cost effectiveness and manage the impact of increasing and changing technology. The key areas of development noted were:

**Motivation Training:** trainees' pre-training attitudes affect motivation in training. Motivation can be maximised by emphasising how training offers personal benefit to the candidate and articulating the positive benefits of training, managing expectations of training as well as providing regular, clear, goals and positive constructive feedback.

**Stress-Resistant Skills:** training should incorporate the use of stressors within training rather than developing the trainees' skills to a level and then introducing stress management. The aim of this is to make trainees more resilient to stress and increase trainees' familiarity with stressful operations by increasing their experience.

**Team skills:** it was identified that trainees that train together and are tested together facilitates better training transfer across KSAs.

**Leadership skills:** accepting that leadership skills are not innate and can be trained is key to supporting the development of leadership skills. This should include skills such as adaptability, and emphasise the importance of the trainee's awareness of the roles and tasks of others. This can be achieved through leadership training incorporating various scenarios with multiple decision points.

**Adaptable skills:** training should focus on the relevant knowledge required and the skills needed to transfer piloting ability across a range of scenarios.

**Metacognitive skills:** these skills relate to a trainee's awareness of their own thought processes that are involved in both learning and performance. Training techniques such as self-explanation encourages trainees to consider and justify their choice of action.

**Complex conceptual understanding and multiple representations:** to increase trainees' capability to perform conceptually complex tasks information can be presented in multiple forms such as graphs, tables, animations and equations.

**Transfer:** transfer of training within training and also between training and line operation can be supported through maximising similarities between the training and transfer environment.

**Imagination and mental practice:** these involve trainees mentally simulating a procedure or task. This can support trainees' ability to integrate different elements of training and procedures. Additionally **worked examples** using negative and positive examples support trainees' learning of rules and steps.

Given the above areas of training and learning research development, it might be expected that some of these will have filtered through into the aviation training community. Indeed many are appropriate for addressing the types of aviation challenge identified in earlier sections.

Another notable development in training science and technology in other domains includes increasing use of serious (computer) games to support development of procedural knowledge and cognitive and metacognitive skills. In the defence environment, these tools include use of first-person shooter games to support decision making training (e.g. see Caird-Daley et al., 2009), adaptable skills training (e.g. see Rabourn et al., 2005) and language and cultural awareness (e.g. Tactical Iraqi - a language and cultural training system used by the US military). The value of such tools is they are low cost, can be used as, when and where required, can incorporate feedback on performance to facilitate learning and, importantly, are games people can play. Where use of serious games, or other synthetic environments, is identified as being used for pilot training in the commercial aviation industry this will be flagged in the subsequent sections.

## 4. DEVELOPMENTS AROUND PILOT COMPETENCES

### 4.1 INTRODCUTION

The results of the literature review are presented around the IATA EBT (2013) competencies, as this fits reasonably well with how research appears to be reported. As such the following sections cover:

- ▶ Aircraft flight path management, Manual flying skills;
- ▶ Aircraft flight path management, Automation flying skills;
- ▶ Situational awareness;
- ▶ Problem solving and decision making;
- ▶ Workload management;
- ▶ Application of procedures;
- ▶ Communication;
- ▶ Leadership and teamwork.

Within each of the above sections, key elements of training are addressed. These include:

- ▶ Training need;
- ▶ Training context;
- ▶ Delivery;
- ▶ Instructor issues;
- ▶ Trainee assessment and evaluation;
- ▶ Training effectiveness and transfer;
- ▶ Organisational attitudes;
- ▶ Recognised literature gaps.

### 4.2 AIRCRAFT FLIGHT PATH MANAGEMENT, MANUAL FLYING SKILLS

#### 4.2.1 Training Need

##### 4.2.1.1 Loss of Control

Pilots' manual flying skills are a concern for industry. The ability to use manual flying skills correctly is a key factor in upset recovery, which if managed inappropriately can result in LOC-I. Over 60% of the accident reports reviewed by the PARC and CAST (2013) identified a manual flying error as a factor in the accident

LOC-I events resulted in the highest number of fatal events over the past decade (CAA, 2011; Field & Lemmers, 2014). LOC-I events occur when the plane exceeds the normal flight envelope and the pilot is unable to maintain control of the aircraft through the use of manual flying skills to prevent or recover from the situation. Upset recovery can require taking over with complete manual flight or adjusting the level of automation to use flight controls in a lower mode. These events are unexpected, and often pilots struggle to define all of the contributing factors, leading to inappropriate recovery action.

#### 4.2.2 Training Content

Manual flying skills are taught during *ab initio* and basic training following completion of ground school modules. The training requires trainees to become competent at completing a series of flight manoeuvres in various settings to achieve a broad range of experience. Due to the focus on meeting targets for manoeuvres and hours, manual flying skill training is reported to be repetitive (PARC & CAST, 2013).

Typically, manual flying skills are not taught during Type Rating Training, as it is assumed trainees already possess the necessary skills. Although this is true to an extent, manual flight in modern commercial aircraft or helicopters is very different to the manual flight taught in small fixed wing aircraft during *ab initio*; *ab initio* training also focuses on normal flight. As such, initial pilot flying training does not reflect well the requirements of manual flying in line operations. In glass cockpit aircraft, manual flying skills are central to management of and recovery from unexpected events, such as automation failures or stalls, spins etc. The aim of training in manual flying skills is to produce pilots who can confidently recover in these situations.

During LOC-I, training and procedures advise that the pilot 'takes over' reverting to manual flight to resolve the issues. Greater competence in manual flying skills enables pilots to devote less capacity to physically flying the aircraft in these situations, enabling them to effectively manage the flight deck, monitoring the automation and maintaining situational awareness. Recently, concerns have been raised about how prepared pilots are for these scenarios and whether their manual flying skills are at the level required. Casner and colleagues (2014) found that pilots received strong initial preparation for manual upset recovery during primary flight training. However, the emphasis was not maintained throughout training, with pilots citing infrequent recent practice.

The International Committee for Aviation Training in Extended Envelopes (ICATEE) was established in 2009 with the aim of reducing LOC-I by developing effective upset recovery training. They recommend that for training to be effective it must support the development of knowledge as well as skill based behaviour. Additionally, the training needs to be realistic; however, there are challenges of creating truly realistic environments, both in terms of the flight envelope and recreating naturalistic pilot reaction, e.g. during periods of high workload or in startle situations (Advani, 2012).

To address concerns about reducing levels in manual flying skills the CAA's Significant Seven report (2011) recommends that pilots accrued 10% more flight hours than are currently specified to progress to a type rating course, this additional 10% being focussed on manual flying skills. However, this may not effectively combat the problem as Ebbatson and colleagues (2010) found that recent flying experience, rather than flying experience overall, influenced their appropriate use of manual control strategies, indicating that skill fade is a concern for pilots of all experience. Initial and recurrent training events should incorporate periods of reduced automation and hand flying. Although many airlines support the use of manual skills in routine line flying to mitigate skill degradation, this study suggests that pilots are unlikely to be aware of their limitations so as to direct their own personal learning.

#### 4.2.3 Delivery

Manual flying skills are taught during *ab initio* and basic training in smaller, fixed wing aircraft. These aircraft typically have mechanical displays and are described as 'stick and rudder' planes. Type conversion training then focuses on learning about the management of the aircraft automated systems, and then simulator sessions flying with the automation, again limiting trainees' experience of manual flight in larger glass cockpit aircraft.

Training should incorporate simulator sessions to enable trainees to practise the manual flying skills required for upset recovery as well as normal flight. The difficulty for implementing this type of training is that the availability of glass cockpit simulators in *ab initio* training is constrained by cost, so starting to develop these skills early is difficult. However, practising manual flight in highly automated aircraft may be beneficial for type training. The literature demonstrates contrasting views about how achievable simulator fidelity can be made to support the training of manual handling skills. One argument is that current technology limits the ability to produce a high fidelity experience of upset recovery. Simulators often do not enable flight outside of the normal envelope, or possess the required features to recreate unpredictable aircraft behaviour and the associated motion. Additionally, there is a challenge in designing simulator sessions to replicate the multi-faceted nature of LOC-I where, depending on the actions of the flight crew, an upset situation can quickly evolve from one type into another (SUPRA Consortium, 2013).

Due to the importance of LOC-I events, upset recovery training (typically simulator based). ICAO (2014) provided guidance on training for Upset Prevention and Recovery Training (UPRT) describing the key technical and non-technical elements needed in the training and specifying the requirements for flight simulation devices to support this. The ICAO requirements are being pulled through by EASA to support changes to training related regulations that should become mandatory in 2018. IATA has also recently published what it describes as practical guidance for airlines for on implementing training for upset prevention and recovery (2015). The relevance of any of the UPRT concepts to helicopter pilot training is not mentioned in any of the documents.

Upset Recovery Training Aid (URTA) has been developed to combine knowledge and simulator training to educate pilots about aerodynamic and flight dynamics principles for flight around the edges of the normal flight envelope. As part of this, SUPRA (2013) developed simulator motion cues to better represent loss of control events in simulators. These cues were evaluated by 12 expert test pilots with experience of stall conditions, and were found to accurately represent stall and spin upsets and therefore were assessed to be acceptable for pilot training. They conclude that capabilities of existing training simulators can be enhanced with centrifuge-type simulators to familiarise trainee pilots with the range of motion experienced in upset recovery and demonstrate the effects on their spatial orientation, situational awareness and control behaviour.

Although the work by SUPRA (2013) demonstrates that it is possible to achieve high fidelity in simulation, few *ab initio* flight schools would be in a position to invest in this technology to support the initial training of manual flying skills. In light of the limited ability to recreate unexpected events in simulator scenario training, knowledge-based training could be used to address gaps, and extra effort invested to ensure that simulator training is neither rote nor predictable.

#### 4.2.4 Instructor Issues

PARC and CAST (2013) found that although instructors and operators were concerned about manual flying skills deterioration, they were uncertain as to how to encourage retention through operational policies and line practise.

#### 4.2.5 Trainee Assessment / Evaluation

A criticism of training and evaluation of manual flying skills is that trainees are presented with a limited and expected set of scenarios. Casner and colleagues (2013) suggest that training and testing the skills required for abnormal events have become predictable for pilots, and does not support pilots' skills in identifying and responding to abnormal events. Casner et al. (2013)



found that when abnormal events were presented unexpectedly, pilots' responses were less appropriate than when familiar test presentation was used. In addition to this there was much variation between pilots. This indicates that current training is limited to preparing pilots to pass specific tests, rather than developing skills that can be generalised to unique situations. This ability to generalise is expected from individuals at an expert level (trained pilots with experience). Research such as Casner's study encourages the need for training that aims to train pilots to be 'resilient'. Resilience provides trainees the ability to adapt their skills to the event in hand, enabling them to manage a wide variety of flight scenarios. The evidence suggests that currently, this is not achieved. Training needs to be designed to address these 'resilience' skills (Plant & Stanton, 2012). Also, varied assessments and unexpected scenarios should be used to support accurate evaluations of trainee capability. Current training and assessment techniques fall short of creating the physiological reaction experienced in real settings.

#### 4.2.6 Training Effectiveness / Transfer

In addition to establishing how well manual flying skills are addressed during training, there is also a need to consider how well these skills transfer to line operations and are maintained throughout a pilot's career.

Trainee pilots are taught manual flying skills in *ab initio*, in aircraft that little resemble the highly automated aircraft they will fly for their Type Rating and subsequent career. The transfer of training between *ab initio* and Type Rating has previously been debated in the literature (Holding, 2012). Some *ab initio* training incorporates technically advanced aircraft to familiarise trainees and recently Type Rating training programmes have introduced an initial manual flying phase. This approach differs from previous approaches, where learning about the automation systems was the initial focus of training, and trainees progressed to flying the aircraft with the automation. The aim of this is to familiarise trainees with the 'feel' of manual flight in a technically advanced aircraft that are often substantially different to the aircraft on which manual flying skills are taught in *ab initio*.

#### 4.2.7 Organisational Attitudes

Different operators have varied approaches regarding the use of manual flying skills during line flight. Some airlines support the use of manual flying skills during low workload periods of the flight whilst some prefer high levels of automation to be used throughout. An example provided by Darrow (2014) in the ICAO Training Report described how a First Officer could not accomplish a hand flown instrument approach, even though he was experienced, due to little manual flying experience. This was influenced by the company's reliance on automation in their Standard Operating Procedures. Use of manual skills in routine line flying and during Type Transition training could protect them from degradation, rather than increasing the hours requirement in *ab initio*. Evidence suggests that the recency of an individual's manual flying experience has a greater influence on performance and skill retention than overall flight hours (Ebbatson, 2010; Wood, 2009).

#### 4.2.8 Recognised Gaps

Increasing use of automation can result in reduced manual flying skill practice and overconfidence in automatic systems. Pilots who have not developed extensive manual flying skills may not get the opportunities to practise and develop those skills, due to an increased emphasis on the use of automated systems. This is especially relevant when considering reduced time to command.

Gillen (2008) found that in having to devote greater effort to manual flight the pilots found it more challenging to manage the additional aspects of the flight. Casner and colleagues (2014)

evaluated commercial pilots' ability to fly with reduced automation and warning systems. They found that although pilots' manual flying and instrument control skills were 'reasonably well retained'; errors in the cognitive skills accompanying manual flight were more frequent and serious. These included issues with establishing situational awareness in navigation, thinking ahead, reconfiguring the aeroplane and managing system failures. This highlights the importance of workload management and prioritisation even when using of reduced levels of automation, and reinforces the need for manual flight training to be conducted in an automation rich, line relevant environment.

### **4.3 AIRCRAFT FLIGHT PATH MANAGEMENT, AUTOMATION FLYING SKILLS**

#### **4.3.1 Training Need**

##### **4.3.1.1 Loss of Control**

Over-reliance on automation in training may impair development and maintenance of operator manual flying skills as addressed in Section 3.2. It can also create an 'out of the loop performance problem' (Clegg et al, 2010). In PARC and CAST's (2013) work group accident analysis, pilots were identified as being 'out of the control loop' in over 50% of accidents. In these situations the pilots over-delegate authority to the automated system control. This results in reduced situational awareness and reduces the pilot's ability to anticipate aircraft behaviour, making it challenging to take control and manage unexpected events. Automation dependency is of equal concern in helicopter operators, with BALPA raising their concerns that new helicopter pilots may rely too heavily on automated systems (CAA, 2014).

##### **4.3.1.2 Mitigating Startle**

The out-of-the-loop problem has also been identified as contributing to pilot startle. Martin (2013) identifies that pilot actions during unexpected events are often inappropriate and violate previous training, and evidences this response with numerous case studies. Hurts and de Boer (2014) found that automation startle is experienced frequently during flight operations, occurring once a month for the average pilot.

##### **4.3.1.3 Levels of automation / mode management**

The selection and transition between levels of automation has been highlighted as a need for further training since being cited in the FAA report (1996). Pilots are required to select the correct mode of automation, dependent on the need of the situation. Research has found that this is still an area of need in training. Nickolic and Sarter (2007) found that contrary to training, when attempting to recover from a disturbance pilots do not come out of high-level automation modes into lower levels of automation. They also found that eight of the 12 pilot participants had inaccurate knowledge about the navigation sub-modes of the flight management system, adding to difficulties in accurate diagnosis and recovery of automation related errors.

Indirect mode changes, where the mode changes automatically, and mode confusion are cited by pilots as common occurrences (PARC & CAST, 2013). Operators and instructors emphasised that there is a need for training to support an understanding of flight path management systems that underlie mode awareness, selection and the need for callouts, rather than focusing on procedure.

Fleming et al. (2013) also found pilots to have poor knowledge of the intended use of levels of automation. The intervention aimed to reduce aggressive responses to the Traffic Alert and Collision Avoidance System (TCAS), which were resulting in the need for upset recovery as pilots often overshoot the required altitude change. The TCAS training developed lasted 50 minutes (reflecting the time available in training programmes) and combined ground based

training and flight training (LOFT) requirements. The study considered direct mode changes, where the pilot changes the level of automation. Only 11% of the experienced pilot participants could identify the correct course of action before the training intervention. However, training reportedly resulted in a significant improvement in pilot understanding and behaviour.

#### 4.3.2 Training Content

Use of automation is addressed during Type Rating training and the later stages of MPL. Previously, it was felt that pilots should be taught how to use automation to accomplish tasks, but not how the automation works, as this detailed understanding was felt to be unnecessary. The emphasis now is on the importance of training pilots to understand as well as use the automation.

The difference between training pilots to use automation or the underlying logic can be explained through procedural and declarative knowledge. Procedural knowledge relates to task specific rules, skills and actions whereas declarative knowledge is a deeper level of understanding and is descriptive and fact based. Wood and Huddleston (2006) identified a gap between pilots' procedural knowledge and ability to manage the automation interface and their system understanding (declarative knowledge) of what the automation was doing and how it was controlling the aircraft. This is used to explain inappropriate pilot response, as failures of automation or displays cannot easily be understood by what they mean to the flight. Training based on procedural steps does not allow pilots to respond optimally in non-normal situations. Suggestions for training include pilots practising choosing the functions to be performed by the automation to develop understanding and decision making skills with regular drill practice reinforcing this learning.

Lyall, Boehm-Davis and Jentsch (2008) recommend that to work in dynamic environments, pilots require a declarative understanding of the flight system. This declarative knowledge requires an understanding of the underlying concepts behind the automation, without this the pilot relies on a procedural understanding and cannot deal with situations that deviate from the norm. They identify best practice as being:

*“To the extent possible, explicitly teach the logic underlying the automation and cover its limitations”.*

They advise that details should be simplified to aid understanding but not oversimplified so as to obscure the logic of the system. Additionally, they advise training pilots about the limitations of automation, giving examples of failures and how to cope with them. Similarly, Wood (2009) emphasised the importance of exposing crews to malfunctions of automation in training, in order to improve their automation knowledge, management and handling skills.

The above also applies to helicopter pilots; current training requirements do not specify the need for an understanding of underlying automation logic, mode selection or the autopilot. Nor do they specify the activities of the Monitoring Pilot role. The CAA Offshore Helicopter Review (2014) recommends that helicopter manufacturers and operators should review the current training material and ensure that the programmes emphasise the role of automation.

Deen (2011) considered the use of automation by military pilots training for operations in high threat environments. During the simulation, crews generally accomplished their intended mission but the quality of their performance was found to vary significantly. The lack of effective set up and use of automation was a predictor of poor performance. The authors establish that automation use was on a continuum, with over or under reliance resulting in lower performance. This report confirmed that the pilot's ability to use the automation is a key requirement for training. Importantly, pilots need to have accurate mental models of how the automated aircraft systems are functioning, how they interact with other parts of the system and the effect of pilot

inputs on them. Therefore, pilots require training in both the understanding and use of automation to a level which means that they are 'fluent' in the operating system of the flight management computers.

The FORCE training programme (Wood, 2009) developed a novel course to train flight automation skills, this included a tool for assessing understanding of automation, which was developed through using a cognitive task analysis to understand the mental models used during flight (further details were not provided). The FORCE study found improvements in management of automation, training preparation of the automation, mode selection, and monitoring for mode and aircraft performance. The training also identified that pilots who had previously completed a Jet Orientation Course made greater achievements during training than pilots who had not.

The use of automation is interrelated with non-technical skills, such as communication, decision making and problem solving. It is advised that training on the use of automation integrates these non-technical elements. A preliminary study conducted as part of the FORCE work sought to link non-technical skills with specific automation related behaviours derived from the literature with an 'automation overlay' to tailor the NOTECHS System (Fletcher & Tennison-Collins, 2007). However, no further evaluation was conducted with of this approach.

#### 4.3.3 Delivery

The majority of automation training occurs during Type Rating training or the equivalent later stages of MPL. It relies on the use of ground school, to teach trainees the underlying system logic, and then simulators to practise line oriented flight scenarios. Ground school uses traditional classroom instruction; this technique is used to present trainees with the core knowledge and skills required as a foundation for further learning. Previous research has found this to be an effective technique for training cockpit automation concepts (Casner, 2003). Other studies have found that scenario-based training (Salas et al, 2006) and guided use of computer-based training (Wood, 2009) can be useful for automation related training.

To get the best from simulator sessions there is a need to facilitate trainees' critical thinking about their own performance (Borgvall, 2011). This can be achieved through debriefs, which should be provided immediately to reduce the delay of feedback as the memory of executions is likely to decline if feedback is delayed, making the feedback less effective. Similarly, consequence-based scenarios aim to encourage critical thinking and better decision making through making pilots follow through with the consequences of their decisions, such as diverting the aircraft (Dornan et al., 2007).

Student and private pilots have been found to regularly use Microsoft Flight Simulator (MFS) as a training and proficiency aid. Although it does not qualify as a basic training device because it does not include physical controls, it offers an affordable way to practise and maintain skills. Beckman (2013) conducted a study with participants including pilots with private, commercial and ATP licenses. Since 2000, 76% of participants used MFS during their training. Specific skills that participants felt were effective in training included interpreting flight instruments, VOR set up and use, altitude instrument familiarisation, cockpit familiarisation, basic manoeuvring and cross country navigation. It was also found to support recurrent training.

#### 4.3.4 Instructor Issues

Many of the instructors interviewed by PARC and CAST (2013) identified that they would benefit from improved guidance on how best to teach the underlying logic of the automation and its use. Currently, information on this is limited. PARC's interviews found that training programmes would have to write their own training manuals as these were not provided by manufacturers, and these would not be regularly updated. Even the manuals produced by the manufacturer

may not explain the underlying system logic in detail. This was also found to be the case for Rotorcraft Flight Manuals, which hold little detail about how to implement training (CAA, 2014).

#### 4.3.5 Trainee Assessment / Evaluation

The FORCE training programme (Wood, 2009) developed a tool for assessing understanding of automation, using cognitive task analysis to understand the mental models used during flight. Further details of the tool were not provided. However, the author emphasises the need to provide an assessment framework for skills that will enable targeted training.

Lyll and colleagues (2008) suggest that multiple assessment techniques should be used to assess trainees' automation management knowledge and skills. These include:

- ▶ Paper tests to establish declarative knowledge;
- ▶ Conceptual knowledge assessment can involve card sorting or concept mapping and aim to assess how individuals organise their knowledge within a domain. The aim of these techniques is to assess conceptual and strategic knowledge and expertise;
- ▶ Simulator evaluation, in either flight simulators or computer-based trainers, should assess behaviour and reactions in abnormal conditions;
- ▶ Line Checks occur during actual flight and can be used to assess typical flight behaviour.

Following LOFT training sessions, instructors provide feedback on learning points identified during the session through their observations. This feedback is provided in a debriefing session which also offers flight crews the opportunity to reflect on their own performance. This process is facilitated by the instructor, and is most beneficial if conducted soon after the session, to prevent loss in memory and saliency of the event (Lyll et al. 2008).

Instructor/evaluator assessment is subjective and for this reason there is often little consistency across instructor/evaluator scores. Factors such as the instructor/evaluators experience of the activity being assessed, company norms, the clarity of competency definitions and even the instructor/evaluators view all influence scoring (Iijima et al., 2011; Tsuda, 2009). Inter-rater reliability training can be delivered to guard against these errors (IATA, 2013) by making assessors more aware of their vulnerabilities, by defining the assessment criteria and supporting the correct use of the rating scales. If an operator or regulator can be confident in the inter-rater reliability of evaluations this supports further analysis and interpretation of performance trends. In the field, implementation of inter-rater reliability is challenging. Currently the extent to which assessors are trained and calibrated to achieve inter-rater reliability is not known.

Digital personnel data collection can be used in the flight training environment. These include programmes such as Flight Operations Quality Assurance (FOQA) and Automated Expert Modelling and Student Evaluation (AEMASE) that collect data from individuals' flights which can then be used in training and evaluation (Vala, 2011). Within the military, automated behavioural and biometric data collection for evaluation has become a major cost driver (Forsythe, 2011); however it provides a great benefit in training feedback and evaluation.

#### 4.3.6 Training Effectiveness / Transfer

Early stages of training take place in an aircraft with simple systems and old instrumentation. Under a traditional training route, pilots move on to highly automated glass cockpits and multi-crew systems relatively late in their training, when they join an operator. However, training on different systems does not support generalisation to 'glass cockpits' and, therefore, it is recommended that this transition takes place earlier in training (Harris, 2009).

Lyll and colleagues (2008) also found that because all automation systems are not the same, knowledge may not transfer well between automated systems. In the worst scenario this can lead to unexpected responses from the automation that the pilot will struggle to interpret. This is especially relevant to helicopter pilots due to wide variation in cockpit design. Although a solution to the variation is consistency in design, training can be used to support transition through mapping an individual's existing knowledge to the current system and identifying the overlaps and gaps. This approach is labour intensive and requires detailed assessment of the trainees' training needs to create a bespoke solution, which may not be possible in the programme timeframe.

Hutchins (2007) examined how pilots' understanding of flight automation develops from ab-initio training through to the first 18 months of line experience. Interviews and observations were analysed to understand changes in their conceptual models over time. The authors found that pilots use simple mental models to interpret the behaviour of the automated systems, and even at 18 months of experience of using the more complex modes (e.g. the managed decent mode), they have not gained a full understanding of how the modes operate.

Nickolic and Sarter (2007) presented 12 airline pilots with a challenging automation-related simulator task. They found that the mental models used by pilots were incomplete. This was demonstrated through their inaccurate understanding of automation modes, which limited their ability to diagnose and recover from automation disturbance (error management). For example, pilots reported strategies such as "pushing buttons until it worked" or "resetting" the system or were unable to explain unexpected behaviour of the plane, reflecting incomplete knowledge of how to deal with the system effectively. The authors noted that potentially unproblematic events could be inadvertently "managed" by pilots into real disturbances from which the pilots then had to recover, i.e. they made things worse because they did not understand what they were doing.

Flight Management System (FMS) training has improved within some operator organisations, but limitations are still prevalent. A survey of airline pilot perspectives on training effectiveness (Holder, 2013) found that FMS training could be improved by addressing operational situations and tasks. Pilots reported that in the first six months of flying their current type airplane, 61% had difficulties completing tasks using the FMS during line operations. Only 25% said they were adequately prepared. Just over 42% of the pilots surveyed believed that their FMS training for the type airplane they were currently flying was minimal and stated there was room for improvement or it did not adequately cover operational use. The survey also showed that 42% of the pilots reported only learning the operational use of FMS during on-the-job flying, and 62% reported that it took 3-12 months of line experience to obtain comfort with using the FMS. The pilots identified specific areas that FMS training could be improved to target:

- ▶ Automation surprises;
- ▶ Hands on use in operational situations;
- ▶ Transition between modes;
- ▶ Basic knowledge of the system;
- ▶ Programming.

All these studies indicate that training may be falling short of teaching individuals the underlying logic of automation systems.

#### **4.3.7 Organisational Attitudes**

As mentioned with regard to manual flying skills, different operators place a different emphasis on the use of automation levels during line flight. This is likely to be reflected in operator training

schedules. Differences across training may impact upon harmonization due to crew expectation and experience.

#### 4.3.8 Recognised Gaps

It is suggested that training for automation is introduced to trainees as early in the training program as possible, in an integrated manner relating automation to other areas (Lyall et al., 2008; Rigner and Dekker, 2000). The literature highlights that CRM and Automation should be taught using an integrated approach.

### 4.4 SITUATIONAL AWARENESS

#### 4.4.1 Training Need

##### 4.4.1.1 General Aviation and Flight Management

Situational Awareness can be considered as a product of a pilots perception of environmental and situational cues, understanding their meaning and projection of how they may change over time. The competences underpinning this of monitoring, recognition and situation assessment, and anticipation are essential for achieving and maintaining accurate situation awareness across all aspects of flight. This includes internal aircraft systems, the external environment, time, other crew members and the wider community.

##### 4.4.1.2 Startle

As identified in section 2.3, Martin (2013) identified that pilot actions during unexpected events are often inappropriate and violate previous training. They conducted a simulator study that a third of pilots demonstrated behaviours and performance levels associated with startle after an unexpected event. This demonstrates high variability across individual factors such as personality traits, emotional state stress and fatigue as well as situation factors such as contextual variables and attention demands.

In their study, Hurts and de Boer (2014) found that on average pilots experienced episodes of startle about once per month. However, the majority were 'incidents' with little or no consequence. A few serious incidents of plane damage or unstable flight were reported, and no accidents were reported. Pilots reported no change or minimal change in their trust of the automation. More difficult flight phases and longer flight duty periods resulted in more frequent experience of automatic startle. This should be addressed in training.

##### 4.4.1.3 Use of Automation

Close monitoring of the automatic systems support pilots' maintenance of skills and enable them to recover from incidents better (Casner et al. 2014). Although automation is meant to support pilot task load by relieving them of repetitive tasks, it has been shown to lead to less situational and system awareness. Casner and colleagues (2014a) assessed the task related and task unrelated thoughts of 18 pilots flying a Boeing 747 400 simulator. Task unrelated thoughts increased when 'all was going to plan'. Task unrelated thoughts were at their highest when the individual was not interacting with the automation. Therefore, although automation is meant to support pilots' ability to plan ahead, monitor systems and consider potential threats, it would appear that pilots only re-invest some of their free attention into flight-related thoughts. Perhaps not surprisingly, Casner and colleagues (2014) found that pilots who relied on the automation and allowed their thoughts to drift were more likely to show deteriorated cognitive skills. They suggest that this is because their 'free time' is not being used for this there is an overreliance/confidence in the automation.

#### 4.4.1.4 Monitoring

The CAA report *Monitoring Matters* (2013) identifies the vulnerabilities and stressors that can result in monitoring lapses, alone and in combination. These include workload, fatigue, attention and distraction as well as cognitive biases such as tunnel vision (focusing on one thing), confirmation bias (seeing what you expect to see), looking without seeing (for example looking at the display but not processing the information it shows) and expectation (failing to consider other alternative actions).

#### 4.4.2 Content

Monitoring is a key component of SA, involving the observation and interpretation of information from the flight deck, including flight path data, automation modes and the relevant on board systems as well as external information and crew members. Pilots are required to compare the observed information with their knowledge of the expected data and procedures. As aircraft become more technologically advanced there is a greater requirement on monitoring skills (Funk, 2009). Good situational awareness is dependent on strong monitoring skills and monitoring is a defence against equipment failure and pilot error and can act as a countermeasure in TEM.

Human beings are not naturally talented at monitoring and it can be a demanding task. As novices, pilot trainees can be overloaded by the amount of information that they are required to process, and their processing is slow and laborious. They need an understanding of underlying systems, and their relationships, to ensure that they attend to the required information. To achieve this, trainees need to acquire a mental model of the aircraft systems and the operational domain. The development of schema can also support situational awareness, however this is reliant on experience and therefore does not generalise to all situations. This finding highlights the importance of linking situation awareness training with that of the aircraft systems and automation.

Situation Awareness (SA) is trained during CRM and TEM. Dismukes and Berman, (2010) suggest that CRM training and checking have become somewhat pro forma and routine, receiving less emphasis in training. Pilots should be trained about potential lapses, such as looking without seeing. Hertz (2014) discusses the construct of situational awareness and suggests that due to the wide definition of SA there is limited prescriptive guidance for training. Individuals need to make meta-cognitive judgements about SA to adopt effective monitoring strategies, enabling them to be flexible to novel situations such as automation failure. By deconstructing SA into its component elements (abstract reasoning, attention, automaticity, dynamics, encoding skill, mapping, metacognition etc.) training could help pilots develop monitoring and control strategies. This approach to the teaching of the constructs also supports assessment of SA skills.

Koglbauer and colleagues (2009; 2011) found that with private pilots, anticipative recovery training both improved simulator performance and showed a significant transfer of training to the subsequent real flights. Training included nine training trials for each manoeuvre (pitch, overbank, stall and spin) across three training sessions where trainees anticipated the action, performed the action and then compared their technique. This was found to provide pilots with the correct anticipations of flight situations and enabled them to manage their anxiety and other flight pressures. They conclude that anticipation training applied in combination of simulator and real flight can be transferred to flight instruction practice.

#### 4.4.3 Delivery

Anticipation of events can be supported by low fidelity training measures. Martin and colleagues (2011) assessed the usefulness of encouraging pilots to discuss of novel or emergency events



as part of routine briefings asking 'what would you do if...?' This aims to reduce the perceived novelty of these events, by increasing pilots' expectation and provide them with a more readily accessible knowledge database. This training technique is much more accessible than simulator time and was found to raise pilots self-reported expectation of surprise events, and their feelings of preparedness for these events. The study group also planned to continue with the discussions after the project finished.

#### **4.4.4 Instructor Issues**

None identified.

#### **4.4.5 Trainee Assessment / Evaluation**

Non-technical skills such as monitoring skills are difficult to assess and often rely upon observation; eye tracking could offer an objective assessment (Schriver et al. 2008).

Sullivan and colleagues (2011) used eye tracking systems to assess the visual scan patterns during a navigation task of 12 military helicopter pilots in a fixed base helicopter simulator. Experts demonstrated superior scan management skills as compared to novices, with their gaze changing quickly between a greater number of views however, performance was found not to correlate with scan patterns. Therefore, the use of 'flight performance' as an assessment measure does not accurately reflect cognitive processes used, thereby limiting its value for testing and evaluating trainees. However, although the ability to assess scan skills is limited, the authors suggest that basic scan skills (dwell duration) and high level scan management (view change) should be trained to support monitoring skills, in light of their relationship with expertise.

Casner and colleagues (2013) criticised the current training as being limited to preparing pilots to pass specific tests, rather than developing skills that can be generalised to unique situations. This ability to generalise is expected from individuals at an expert level (trained pilots with experience). Varied assessments and unexpected scenarios would support a more accurate evaluation of skills. Current training and assessment techniques fall short of creating the physiological reaction experienced in real settings. The role of surprise, which can lead to startle, is not to be underestimated.

#### **4.4.6 Training Effectiveness / Transfer**

In their study observing operational flights, Dismukes and Berman (2010) observed an average of 6.5 monitoring deviations was observed per flight, including late or omitted callouts, omitted verification, and not monitoring aircraft state or position. They suggest that humans are poor at monitoring infrequent events such as equipment failures, additionally pilots do not receive feedback on the efficacy of their monitoring and they are therefore unlikely to realise that their monitoring is inconsistent. Individuals have a limited cognitive capacity, although selective attention can be used to attend to multiple tasks. High workload or physical and mental distractions can fully occupy the individuals cognitive capacity and cause task shedding.

#### **4.4.7 Organisational Attitudes**

None identified.

#### **4.4.8 Recognised Gaps**

When interviewed about their perceptions of training, although 99.3% of respondents identified monitoring as an important skill just over half of the pilots surveyed reported that monitoring skills, such as detecting and managing errors, was not covered explicitly or in detail during their recurrent training (Holder, 2013). This indicates a need for guidance materials for training monitoring and cross-checking skills. The authors suggest pilots would benefit from monitoring

being presented as a primary task along with workload management strategies in order to prevent secondary task demands and complacency from having a negative impact on monitoring.

Monitoring and situation awareness are open to other human vulnerabilities that may impact pilot performance, for example, attentional tunnelling, which occurs when individuals focus on certain aspects of a situation, intentionally or inadvertently failing to scan for other aspects. Although the individual will have good awareness of the aspect of the flight they are focusing on, their awareness of the other cues will deteriorate, undermining their situational awareness (Wickens, 2005; Wickens & Alexander, 2009). Additionally, stressors such as workload and fatigue reduce the capacity of working memory and lead to task shedding, where individuals pay less attention to peripheral information (Dismukes & Berman, 2010). Further research could examine the influence of these areas and consider how training techniques and strategies emphasising metacognitive skills in pilots could protect against these safety risks.

As part of the European Man4Gen project, Rankin (2012) identified a number of areas of focus for future training. One of these was 'sensemaking'. Sensemaking has a role in monitoring and anticipation and occurs when there is incongruence between what is observed and what was expected. Research into this area may support an understanding of how pilots perceive and interpret information and how this can be better supported by the system.

## **4.5 PROBLEM SOLVING AND DECISION MAKING**

### **4.5.1 Training Need**

#### **4.5.1.1 Loss of Control**

Due to the variety of events that can be encountered that may lead to a LOC-I, it is impossible to train pilots for every eventuality. Plant and Stanton (2012) suggest that to mitigate this risk, training should not focus on teaching rules (if...then...) to trainees, but instead encourage them to approach problems like an expert by being adaptive and resilient. They suggest this can be achieved through providing trainees with the appropriate knowledge and experience, however these are not defined.

#### **4.5.1.2 Go-around**

Go-around due to rejected landings, or indeed any late change in plan, is a challenging manoeuvre. Go-arounds may be ordered by air traffic control or determined by the flight crew in light of flight conditions, such as an unstable approach. The industry has identified them as a safety issue because they are often either poorly executed or a decision is made to continue the landing when a go-around should be performed.

#### **4.5.1.3 Overall Flight Management**

Decision making and problem solving are a central part of operating a modern aircraft. Multiple decisions of different types are made throughout any one flight, sometimes this will include problem solving and decision making in emergencies, and other times it will involve more routine decisions and even choices that are so automatic a decision barely seems to have been made. Effective skills in all of these situations are essential and under all flight circumstances, including in response of unexpected events.

### **4.5.2 Training Content**

Decision making is a key competency in CRM and, more broadly in TEM. However, in general, aviation training organisations do not have specific methods or techniques for decision-making instruction during ab-initio training. The ability to make decisions in the air has often been regarded as by-product of flying experience rather than training (Li et al., 2011). Although

knowledge and skill can be gained through pilot training, judgement is either seen as a trait possessed by an individual, or something gained through flying experience over time.

The use of mnemonics and acronyms is common to support decision making best practice for pilots. These approaches aim to support a systematic approach to decision making. These techniques have been found to be very effective. Li and Harris (2008) found trainees demonstrated better decision making following a four hour course that taught the trainees decision making models, the role of situational awareness in decision making and the mnemonics Stimuli, Hypotheses, Options, Response (SHOR) and Detect, Estimate, Set safety objectives, Identify, Do, Evaluate (DESIDE). These results were replicated in Li and colleagues (2014). Further research has identified that different acronyms are better suited to different situations. SHOR has been found to be best in time limited, urgent situations (and also works well with uncertainty), DESIDE is advantageous in guiding knowledge based decisions but is time consuming, and Facts, Options, Risks & Benefits, Decision, Execution, Check (FOR-DEC) is a good overall decision making tool and is also effective when used under time pressure conditions (Li et al., 2014; Li et al., 2011).

The review of the literature found no evidence of how these are incorporated into training. The use of these mnemonics across training could support multicultural teams and harmonisation. The pilots interviewed reported that it was very important to practise the use of mnemonics in simulation before they are used in actual flight. Initially trainees can demonstrate slower decision making when using mnemonics, but additional practise may increase response time. The programme developed was simple, short and cost effective, providing significant gains in decision making performance. Similar courses could easily be integrated into current crew resource management or simulator-based training programs.

Eurocopter developed a serious game to train decision making in a helicopter cockpit. As well as combining different tasks with different scenarios, the player is also able to play as different crew members. The objective of the game is to put the player (pilot) in a cognitive overload situation so as to practice making decisions in high pressure environments. The game is followed by a debriefing, where instructional videos are intended to support learning. Unfortunately, no measures were reported to indicate the efficacy of this technique and it is likely that this game has similar limitations to those identified with flight simulator training, where the limited number of possible scenarios reduces the pressure on the learner.

Metacognitive skills refer to an individual's awareness of their own cognitive processes and how they may be influenced by information from the outside world. Trainees who have metacognitive skills are able to be critical of their own thinking and learning processes, enabling them to adapt well to novel situations and optimise their use of knowledge. Metacognitive skills play a role in decision making, which can be affected by decision making biases: heuristic rules that can speed up the decision making process through shortcuts, but can cause errors. Examples of these include: the tendency to rely too heavily on one piece of information when making a decision (anchoring bias); and only seeing evidence that confirms a previous belief (confirmation bias). Tiley and colleagues (2011) suggest that training techniques such as self-explanation, where a trainee justifies their choices and actions in situations where multiple action courses are possible. This is thought to improve training and training transfer. This process is similar to the 'hangar talk' technique described by Kearns and Sutton (2008). This technique gathered narrative descriptions of threats and errors encountered by pilots in general aviation. The operational stories can then be used to target the development of nontechnical skills, supporting development of skills during training and throughout the pilot's career.

Anticipation can be viewed as another metacognitive process aimed at optimising cognitive resources it is a key part of situation awareness and is definitive of expertise (Lini, et al. 2012).

Lini and colleagues (2014) attempted to facilitate pilot anticipation to support decision making skills and cockpit resource management through developing Anticipation Support for Aeronautical Planning (ASAP). The model combined: performance objectives and risk assessment at the highest level; at the mid-level it considers the exploration and exploitation of new and existing solutions; and the lowest level relates to implementation. The model aims to support a human cognition focus of training expertise, avoiding reliance on automation. Information about the efficacy of this approach was not available.

#### 4.5.3 Delivery

Non-technical skills, such as decision making and problem solving, can be trained and assessed in flight simulators. Scenario based training facilitates the development of critical thinking and decision making skills (Salas et al., 2006). Research suggests that the simulators used to train threat and error management (TEM) may need more fidelity of motion because of the cues required for decision making such as movement cues. Kallus (2009) found those who experienced motion based training outperformed the no-motion group and those with no specific training (control) and instructor ratings mirrored this. Motion supports the trainee pilots in developing a mental representation of what is happening and this supports trainees' recognition and mapping of mental cues. To achieve this, LOFT and flight simulators should incorporate variation of cue numbers, properties and scenarios providing multiple decision points to improve pilots' awareness of cue relationships.

As part of the European Man4Gen project, Fucke's (2014) report into situation awareness assessed crew and pilot behaviour during a complex simulator scenario with multiple decision points, multiple landing options and elements of ambiguity. The high performing groups were more consistent under high workload and demonstrated competency problem solving and decision making, whilst low performing crews did not. These differences would not have been visible in a scenario where participants could anticipate the decisions and actions required. Current training preparation for unexpected events has been criticised for its focus on a small number of training scenarios that come to be expected by the trainees. This suggests that there is a need for training to target decision making and problem solving to provide a more consistent result across crews. Training and assessment scenarios need to better assess these skills to provide a realistic assessment of competency. Gaps in trainees' ability should be identified and dealt with prior to the pilot being confronted with complex situations during line flight.

Beckman (2009) reports the ability to use MFS to teach concepts of aeronautical decision making in classroom settings. This was achieved through demonstrating flight problems and offering trainees a view from the outside of the aeroplane. They describe the use of the simulator to teach aerodynamics, aircraft systems, weather and navigation (including automatic systems). This is achieved by using different views offered by the software and encouraging discussion. Although in the 2009 study, the use of this computer-based training was found to be successful in training decision making skills, Beckman (2013) found participants felt that aeronautical decision making was less well supported the approach. However, no objective data on knowledge or assessment of skills were offered.

#### 4.5.4 Instructor Issues

Training programmes require instructors to develop flight simulator and LOFT scenarios to train and assess trainees. This places pressure on instructors, as there is a need (as outlined in this report) to include multiple factors in scenarios, avoiding predictability whilst accurately reflecting line operations. Simulator scenarios with multiple decision points have been found to be more effective in establishing flight crew capability (Fucke, 2014). In addition to this, instructors are required to be reflexive to the training/assessment situation, accounting for the trainees'

behaviour or aptitude (Dornan et al., 2007). Winter and Fanjoy (2011) found that instructors referenced a lack of training before beginning to teach students on technically advanced aircraft. Instructors would benefit from structured programmes to support their use of the training tools available to them, (Lubner, 2013).

#### 4.5.5 Trainee Assessment / Evaluation

Research studies are able to use eye tracking to measure pilot attention in simulated flights, to explore how this influenced decision outcomes (Schriver et al, 2008; Sawyer & Shappell, 2009). These studies enable us to understand how individuals make decisions, as this is difficult for trainees to report and instructor/evaluators to observe. For example, Schriver and colleagues (2008) found that if experts or non-experts noticed a single diagnostic cue, they often respond appropriately, but experts were more likely to notice and respond to problems indicated by patterns of cues. The findings support the link between greater attention and more effective decision making. As different attention strategies were used by experts and novices, it would be beneficial to be able to assess which strategies trainees are using. Non-technical skills are difficult to assess and often rely upon observation; eye tracking could offer an objective assessment. Unfortunately this level of measurement is difficult to achieve in training assessments without technological support. As costs of this type of technology (and others) are notably decreasing over time, there may be a greater opportunity to integrate them within training assessment in the future.

#### 4.5.6 Training Effectiveness / Transfer

To facilitate decision making pilot trainees need to gain experience of distinguishing cues and interpreting them correctly. Sawyer & Shappell (2009) assessed the impact of cue based training on weather related decision making with participants that did not have flying experience. Cue based training identifies and teaches specific cues that signify a change in system state which require a specific response. Eye tracking was used as an assessment measure to determine what participants looked at and for how long to give an idea of underlying decision making processes. Although decision accuracy was not improved by the training program, eye tracking showed that after training on which weather features are important, participants made decisions using fewer visual fixations and less total gaze time, indicating that the processes behind decision making may have become more efficient. Strategies for supporting decision making were not discussed.

#### 4.5.7 Organisational Attitudes

Operators are required to make trade-offs to meet budget and time constraints, whilst still training the necessary KSAs. Most training courses do not have time to teach trainees about line operations, and instead focus on trainees passing assessments. The PARC and CAST study found that training is limited in its ability to be flexible to trainee needs (2013). Their interviews highlighted challenges related to programme structure including the ability for trainees to learn problem solving through making mistakes, and teaching decision making and command judgement.

#### 4.5.8 Recognised Gaps

Improved decision making could play a role in mitigating startle. Through using a metacognitive approach and being aware of decision making biases, pilots could be more prepared to manage these unexpected events. Kochan and colleagues (2005) suggest that a pilot's response to unexpected events can be improved through *cognitive flexibility training* (to encourage flexible responses to surprise events), *adaptive expertise training* (to reinforce positive responses to surprises), and *metacognitive training* (to teach pilots how to evaluate their mental processes in responding to surprise).

Unstructured decision making in teams, relying on assumptions and preferences, are a contributing factor in accidents (Steinhart et al., 2014). None of the literature reviewed for this report addressed training for team decision making.

## **4.6 WORKLOAD MANAGEMENT**

### **4.6.1 Training Need**

#### **4.6.1.1 Overall flight handling and management**

Workload management is a key competency across all aspects of flight operation, and should be considered across the curriculum. It is important with regard to all of the main aviation safety concerns:

- ▶ A reduced ability in manual flying skills increases pilot workload when these skills are required making management of additional flight aspects challenging;
- ▶ Due to the change of workload from low to high pilots find it challenging to take control and manage unexpected events;
- ▶ Pilots struggle with mode selection decisions, indicating a confusion of what level of automation (and workload) is appropriate for different tasks;
- ▶ High levels of workload can lead to deviations and errors in following SOPs and checklists.

### **4.6.2 Content**

Managing flight deck tasks requires task prioritisation, management of workload, management of attention and information and time management. Tasks can also be shared by the Pilot and the Pilot Monitoring. Most airlines do not explicitly teach skills and strategies for workload management, although elements may be integrated into TEM and CRM training (PARC & CAST, 2013). Training often focuses on mnemonic techniques, such as the long-standing mantra: Aviate, Navigate, Communicate, to support pilots' decisions regarding workload management and prioritisation. Although effective during normal operations, these mnemonics do not account for situations involving high numbers of tasks, tasks that are 'shelved' for completion later or tasks in overlapping areas. If a pilot is overloaded, they will shed tasks. Without explicit training, this is achieved through pilots developing their own techniques, resulting in tasks being shed in no particular order. As a consequence, workload can impact across all pilot skill areas.

### **4.6.3 Delivery**

Kearns (2011) conducted a study with 36 PPL licensed pilots and found that single pilot resource management (a lone pilot version of CRM, focusing on workload) could be trained using a computer based simulator and guided mental practice (using video), resulting in specific improvements in situational awareness. This indicates that through effective workload management, the availability of additional capacity can benefit other operational skill areas. The author discusses that to generalise this method to CRM additional work is required to assess team training methods and how these could be trained by computer-based training.

Dahlstrom and Nahlinder (2009) measured heart rate to show the physiological responses of eight trainee pilots in simulator and aircraft training. The participants' heart rates were consistently lower in the simulator, indicating higher workload in the aircraft. Unexpected events in the aircraft also created a higher physiological response, whereas in the simulator participants demonstrated expectation effects of knowing when incidents would happen. This shows that the trainees were more able to handle higher workloads or unexpected events in the

less demanding simulator setting. The authors suggest that the additional demands of flying an aircraft (looking out for traffic, weather etc.) increase the workload of the pilot. This could help explain the incidence of startle, in that training does not adequately prepare pilots for operational working demands.

#### 4.6.4 Instructor Issues

None identified relating to pilot training *per se*.

Challenges were identified for the instructors regarding their own workload and the demands on them as a community. Research indicates that training programmes put a lot of pressure on instructors. This could be influenced by the high turnover of the instructor population, due to the use of the role to gain flight hours before further training. Instructors are often required to learn on the job and have a high workload (Lubner, 2013; Winter & Fanjoy, 2011; IATA, 2013). Instructors need structured programmes to support their use of the training tools available to them, such as confidence in the use of simulators to ensure their use is integrated within training (Lubner, 2013). Winter and Fanjoy found that overall instructors were less supportive of using a technically advanced aircraft as a primary training aircraft, referencing a lack of training before beginning to teach students.

#### 4.6.5 Trainee Assessment / Evaluation

The evaluation of workload management is likely to come under the bracket of CRM skills and would be evaluated subjectively by instructor/evaluators. It can be assessed during LOFT and flight simulator scenario. However, as discussed previously (section 4.2.3), the fidelity of this training is reliant on the scenario accurately reflecting the complexity of normal or non-normal flights.

#### 4.6.6 Training Evaluation / Transfer

It is challenging for training and assessment to accurately reflect the workload requirements of line flight. In addition to the need to train for non-normal events, the levels of automation within technically advanced aircraft mean pilots often experience line flight with long periods of low workload and occasional periods of high workload. It is not realistic to train this using the simulator due to the pressure on the resource, so it is likely that line operations will be the trainees' first experience of this.

#### 4.6.7 Organisational Attitudes

Workload pressure can come from organisational structure as well as the cockpit. As discussed in Application of Procedures, organisations should ensure that their operational priorities are clear and support safety at all times to balance competing goals. An operational focus on time performance and quick turnaround for time and fuel efficiency could cause pilots to rush, create conflicting objectives or increase their workload (Li et al., 2011). A clear operational stance and training on how to manage priorities would support pilots' workload management and decision making.

#### 4.6.8 Recognised Gaps

It is well recognised that increased workload results in a physiological response, which can lead to stress. Stress management training is usually included in CRM education however details on how it is addressed are not readily available. Studies exploring stress training do not generalise well to the trainee pilot population, and result in only minor gains. For example, Fornette and colleagues (2012) found that stress management training does not usually address the causes of stress and suggest that training techniques used do not aim to enhance metacognitive abilities. Through a study with 21 military pilots they found that cognitive-adaptation training prior to trainees first aircraft flight did not have a significant effect on flight performance, mood and

anxiety scores, but trained cadets reported changing their stress-management mode. Details of the cognitive adaptation training were not outlined and as the study considered stress building up to an event (first flight) the results cannot be generalised to stress responses for infrequent events and those that come on without warning, i.e. those that may cause startle.

Similarly McClernon and colleagues (2011) found that training stress coping mechanisms to non-pilot students alongside skills in the simulator resulted in better flight performance in an aircraft than those who did not receive the stress exposure training. The stress mitigation techniques attempted to support task focussed coping suggesting the participant: focuses on maintaining normal breathing; focuses on the task at hand; and pays close attention to flight parameters. The study concludes that by incorporating stressful situations in flight training pilots may be more prepared to cope with stressful flight environments and to mitigate some preconditions of aircraft accidents that are susceptible to stress. However, as the participants had no prior flight experience, the research cannot be generalised to professional pilot trained.

## **4.7 APPLICATION OF PROCEDURES**

### **4.7.1 Training Need**

#### **4.7.1.1 Loss of Control**

Standard operating procedures are a key safeguard in threat and error management on the flight deck. However, checklists and monitoring sometimes fail to detect the errors that they are meant to protect against. Dismukes and Burman (2010) found that whilst most deviations from procedures resulted in no outcome other than slightly reducing safeguard efficacy, a small number (around 10%) of deviations led to an undesired aircraft state. This demonstrates how SOPs may not adequately support TEM.

#### **4.7.2 Content**

SOPs are type specific and are covered during type rating training and helicopter operator conversion training (CAA, 2014). Typically they cover normal and non-normal (emergency) procedures and operator specific requirements regarding pre-flight, departure, en route, and arrival phases of flight. MPL courses focus on training SOPs from an early stage because they are airline specific.

Checklists are used to support pilots' execution of SOPs, increase reliability and as safeguards to protect against error. Previously pilots were required to take reams of paper checklists into the cockpit. This has now been streamlined with the introduction of the electronic flight bag, a computer tablet, however in terms of content there has been little change.

Communication and cross checking between pilots is an important factor, and has been increasingly formalised in SOPs. The breakdown of communication often characterises poorly performing crews (PARC & CAST, 2013; Fucke, 2014) In an assessment of LOSA narratives, briefings and communications of intent between pilots were found to be important, featuring significantly in proactive threat management behaviours and helping the crew to avoid error (PARC & CAST, 2013). Although mnemonic techniques such as Verbalise, Verify, Monitor (VVM) and Confirm, Analyse, Monitor, Intervene (CAMI) are used in training, accident analysis still finds poor communication is a contributing factor to accidents. Within the PARC study, operators indicated they would like further guidance and training on cross verification methods.

Rantz and colleagues (2009) assessed the role of behavioural intervention on the appropriate use of paper flight checklists. They found that providing graphical feedback and praise to participants regarding their use of checklists greatly increased the correct use of checklists, reducing errors to give near perfect performance and the effect was maintained after training.



This was especially relevant as some of the participants' baseline performance was poor. This was suggested to be because of poor initial flight training, no feedback during flights and no negative consequences for failing to use the checklist accurately.

#### **4.7.3 Delivery**

Following ground school, trainees apply their knowledge of SOPs in simulator sessions with scenarios that mimic line operation. However, no details were found in available literature about how these skills, or application of the knowledge, are actually trained.

Type rating training is likely to set up many expectations and habits that the pilot will later rely on in line operations. EASA (2012) emphasised the importance of creating good habits through providing trainees with an understanding of the why behind operating procedures. They use the example of checklists, suggesting that a relaxed approach in transition training may encourage deviations in line operation.

#### **4.7.4 Instructor Issues**

Instructors were found to have varying familiarity with line operations, between and within training programmes. This was especially evident with ground and simulator instructors, limiting their ability to address line issues (PARC & CAST, 2013). The Offshore Helicopter Review (CAA, 2014) recommends the requirement for instructor tutor training is reviewed, especially to support type rating instructors' knowledge of aircraft and the operating environment.

#### **4.7.5 Trainee Assessment / Evaluation**

None identified.

#### **4.7.6 Transfer of Training**

Although SOPs are emphasised in training they may not transfer well to line operations. Li, Hsu and Harris (2013) conducted an analysis of accidents within the Republic of China Air force using a systems approach. They found a high frequency of errors in pilots neglecting or applying the wrong SOPs. Dismukes and Burman (2010) evaluated checklist in typical flight conditions. They found great variability across flight crews, but a high number of deviations overall. The main procedural deviations regarding checklists were checks being performed as a read through and responding without physically looking at the system being checked.

The authors suggest that training could act as a countermeasure.

- ▶ Pilots should be trained on their inherent vulnerability to checklist and monitoring errors, and on procedural measures and practical techniques to counter it;
- ▶ Develop techniques to provide detailed feedback to pilots on checklist and monitoring performance;
- ▶ Place greater emphasis on checklist use and monitoring in air carrier flight standards (line checking) programs;
- ▶ Develop formal mentoring programs for new first officers.

The PARC and CAST report (2013) explored the frequency and conditions in which a pilot may intentionally deviate from SOPs. The majority of respondents cited deviating like this once a year or less because it was necessary in their own judgement for safety reasons. A small number of respondents reported that they would never deviate from SOPs and others reported deviations as frequently as every flight. This self-report methodology is limited by the respondents understanding of what constitutes a deviation (for example, missing an item from a checklist or continuing an unstable approach). Additionally, it is reliant on individuals' awareness of their own deviations.

Additionally PARC and CAST (2013) found errors in primary operating procedures, relating to failure to properly configure systems, poor planning for contingencies, poor coordination between the pilots, and problematic use of the FMS. Man4gen assessed crew and pilot behaviour during a complex and ambiguous simulator scenario with multiple decision points, and found that low performing crews showed weaknesses in application of SOPs even in low workload situations. This could suggest areas where training can be targeted and encourage reinforcing of these skills. (Field et al., 2012)

MPL introduces SOPs much earlier in training. This could be beneficial in framing the information trainees are taught, however, there is currently no evaluation evidence available regarding the influence this has on line flying.

#### 4.7.7 Organisational Attitudes

Dismukes and Burman (2010) suggest that organisations can be used to develop procedures and policies to better support pilots. These suggestions include:

- ▶ Formalizing monitoring and challenging requirements and procedures;
- ▶ Minimizing checklist items involving multiple components and specifying responses for each component;
- ▶ Organizations should periodically review cockpit operating procedures to identify and relieve “hotspots” where task demands are high and interruptions are frequent;
- ▶ Organizations should systematically analyse the entire body of explicit and implicit messages given their pilot corps to balance competing goals;
- ▶ Organizations should examine the role of organizational procedures in vulnerability to error in the cockpit.

#### 4.7.8 Recognised Gaps

SOPs are specific to the operator with whom the pilot is flying, When considering deviations from SOPs Dismukes and Burman (2010) were surprised to find that the time constraints imposed by flights running late did not influence the number of deviations observed, however crews on their first flight together or on their first day of flying together made substantially more deviations. This could possibly indicate additional needs in CRM training as it would be hoped that crews would be able to perform well together immediately in light of their prior training and experience. The authors were unable to make conclusions of effect that pilot and first officer experience has on the number of deviations as their participants did not represent a wide skill range, however they did indicate that there was a small effect. Therefore, it is possible that reduced time to command could have an effect on the frequency of deviations.

Other aspects that could impact upon adherence to SOPs include the ability to prioritise tasks, workload and stress. Training based on procedural steps does not allow pilots to respond optimally in non-normal situations. Suggestions for training include encouraging trainees to understand the underlying systems and why procedures are in place.

### 4.8 COMMUNICATION

#### 4.8.1 Training Need

##### 4.8.1.1 Loss of Control

The PARC and CAST (2013) report identified communication and cross verification errors as key skill deficiencies when analysing accident reports. TEM requires crew members to ‘trap’ the errors within the group, this requires strong verbal communication.

Communication is a key skill required to identify and manage loss of control events. Fucke (2014) assessed crew and pilot behaviour during a complex simulator scenario with multiple decision points, multiple landing options and elements of ambiguity. They found that high performing groups that demonstrated competency in communication were more consistent under high workload whereas low performing crews did not demonstrate these competencies and showed weaknesses even in low workload situations (Field et al., 2012).

#### 4.8.1.2 Go-around

In addition to decision making, crew communication is key when deciding whether to execute a go around. The ability of crew members to challenge each other's decisions, even if the challenge goes against crew member rank is central to the safe operation of an aircraft, and was a driving force behind the development of CRM in the 1970s.

#### 4.8.2 Content

Although communication takes a central role in MPL and MCC training, with the aim for CRM to be a continuous focus throughout, there is little information available about what competencies CRM training addresses and how they are addressed in training. Indeed, this was found across all areas of CRM – other than information on the importance of CRM and the focus on TEM, specific details on techniques are lacking, or older than five to 10 years. Several different definitions of CRM competencies were seen across the literature demonstrating that training is not implemented in a systematic way, suggesting great variability in what is taught and the teaching methods used (Salas et al., 2006; Dahlstrom et al., 2008; O'Connor et al., 2008).

Communication and coordination between flight crews and air traffic control have been found to have consequences on safety and affect flight path management. Recently simulation has been used to support collective training. Traditionally, trained students from across aviation have limited awareness and knowledge of other specialisations that they will be required to work closely with in day to day work. The MTSU Centre for Research on Aviation Training is a NASA funded project that built a replica of an airline's flight operations centre, the aim of the simulator was to encourage and understand 'best practice' across specialism, supporting interaction between aviation specialists (Craig, 2011). Interpositional knowledge has been identified as supporting effective coordination, and is lacking in aviation trainees (Littlepage et al., 2011) The simulation was found to support trainees mental models of other specialisms through accurately reflecting a multi-team environment (Georgiou et al., 2013) and enhanced team work and performance (Littlepage et al., 2013)

#### 4.8.3 Delivery

It was found that throughout the literature reviewed, information was provided about the overall effectiveness of non-technical skills training, rather than considering how individual competencies are taught and assessed. Teaching methods include lectures, practical exercises, role playing, case studies, and video of accident re-enactments (IATA, 2013).

Initial CRM training occurs in a classroom setting, followed by scenario-based training to develop and maintain skills for line flight. In 2004, Thomas highlighted the potential benefits of more extensive scenario-based training on CRM skills. A benefit of scenario-based training is that it supports trainees in integrating technical and nontechnical skills. Recent research emphasises the use of interactive training methods to train the use of non-technical skills, such as communication, for unexpected events through Barshi (2015).

Training preparation for unexpected events tends to focus on a small number of training scenarios, and these come to be expected by the trainees. Kearns and Sutton (2011) suggested that hangar talks can be used as a form of recurrent training to raise pilot's

awareness of unexpected events and explore the use of communication and other non-technical skills such as decision making to address these. Kearns suggests that this discussion of experience could mitigate the reduced experience of pilots who have reached command with less flight hours due to industry growth. Fornette and colleagues (2012) discuss a similar technique used to train French military crews to manage unexpected events through cognitive-adaptation training using interactive training methods such as discussions regarding practical experiences. This training aims to improve cognitive and emotional adaptation skills to manage complex and unforeseen situations, encouraging resilience.

As the technological sophistication of flight training devices and simulators increases there is a lack of understanding in how these can best be utilised to train non-technical skills. This is likely to be due, in part, to the variation in defining competencies and how they are taught. Dahlstrom (2008) emphasises that this can result in educational resources being under-utilised or misapplied. Additionally, time pressure in type rating training can mean that the focus within the simulator is on learning the automation, rather than in practising non-technical skills (Rigner and Dekker, 2009). Introducing technologically advanced aircraft in *ab initio* training could mitigate the time constraint. There is a need for an understanding of how simulators can best support non-technical skills, to provide instructors with a level of guidance and assessors with a structure for competency assessment. This would support a more systematic approach to non-technical skill training whilst reducing the pressure on the instructors/assessors.

#### 4.8.4 Instructor Issues

It has been suggested that the effectiveness of CRM training and competency-based training is linked to the quality of delivery, rather than the training content (IATA, 2013). A facilitation-based approach, whereby crews are encouraged to explore experiences and different situations and reflect on their own performances with the support of the instructor, is outlined as a technique thought to improve efficacy. The extent to which these techniques are used in training currently is not known.

#### 4.8.5 Trainee Assessment / Evaluation

Assessment of CRM competence and non-technical skills is challenging. Observations are used to assess behaviour and checklists to accompany these observations vary in detail from 'Demonstrated good CRM?' to a comprehensive competency checklist, e.g. as through NOTECHS (Flin et al., 2003). Typical assessment procedures rely on two or more assessors to observe and rate a LOFT session. The assessors then compare their ratings together and with a standard score to minimise variation. This means that raters could adjust their scoring in light of others opinions or in light of their knowledge of the mean. Without a prescribed approach structure to guide a final assessment, biases could have an impact.

Limitations in trainee assessment and the lack of detail available in programme and academic literature regarding course composition limits the ability to evaluate these courses at a lower level and explore the efficacy of training competencies such as communication. Overall, there is evidence from CRM evaluation studies that trainees respond positively to training. O'Connor and colleagues (2008) conducted a meta-analysis of 16 CRM evaluation studies and found large effects on attitudes and behaviours and a medium effect on knowledge. The evaluation of training efficacy plays a key role in the development of training in the long term. This gap in understanding is likely to prohibit the progression of training techniques.

#### 4.8.6 Training Effectiveness / Transfer

The PARC and CAST report (2013) found that even though CRM training was felt to be effective, crew coordination and cross verification issues were found in many accident reports. It was also felt that these lacks in communication and co-ordination are likely to be a wide

spread, normalised approach due to the lack of negative consequence from not following procedure. This indicates poor transfer of training and the importance of feedback to reinforce correct behaviour.

Within Threat Error Management, communication and cross checking between pilots is an important factor, and has been increasingly formalised in SOPs. Although SOPs formalise pilot actions to an extent, communication skills have been shown to discriminate between high and low performing crews (Field et al., 2012). In an assessment of LOSA narratives, the use of briefings and communications of intent between pilots were found to feature significantly in proactive threat management behaviours and helping the crew to avoid error (PARC & CAST, 2013).

#### 4.8.7 Organisational Attitudes

There is some dispute within the literature regarding how CRM training is actually provided. O'Connor and colleagues (2008) report that typically CRM training is delivered in two days or less; often it is not a high operational priority. Rigner and Dekker (2009) identified some confusion, where type rating instructors wrongly believed that CRM was addressed in *ab initio* training. They also found that due to type training needing to cover automation skills, there was less opportunity to develop non-technical skills in relation to the systems in the new aircraft, resulting in an overreliance on classroom CRM training. They emphasise the need to integrate CRM training throughout flight training, and not treat it as separate to automation. This has been a key conclusion of numerous reports into pilot training. As it is still being identified in recent literature there is an assumption that it is yet to be adequately addressed.

#### 4.8.8 Gaps

As the demand for pilots increases, it is likely that crews will be composed of individuals from different countries and training backgrounds. Dahlstrom and colleagues (2008) consider the impact of the use of pilots from different countries on CRM. They emphasise that although these pilots are likely to be experienced, there are possible barriers to the use of CRM in cross cultural crews. An example of this is the increased cognitive demand of communicating in English as a second language during emergency situations; the Dahlstrom et al. suggest that this should be specifically addressed in conversion training. The authors highlight that even routine communication should be considered so as to avoid possible miscommunications and misunderstandings.

Related to this, evidence suggests that the ability to challenge or 'speak up' is still a safety issue today. Boeing conducted a survey of airline pilot perspectives (Holder, 2013) and found that although the 'Pilot Monitoring' individuals in a co-pilot role showed high levels of assertiveness, the influence of rank was identified when assessing why go-arounds were not initiated during go-no-go rejected take offs. This is also relevant to wider piloting activities. Ya-Jie and Jing, (2011) identified issues where the captain does not accept safety recommendations from the crew or the crew does not express an objection to unsafe actions. They cite overconfidence and crew relationships as being causal for this. For example, fear of challenging the captain, or challenging in a polite, indirect fashion, suggest that a 'one ballot veto' should be used so that the captain accepts the advice and takes immediate action once any crew member shows uncertainty or objection. It is surprising that these issues are being raised in the literature as it would be expected that this would be well covered in CRM training syllabuses, however, clearly gaps still remain.

As airways get busier there will be a greater reliance on communications. Much *ab initio* training focuses on aircraft control and then encourages the development of communication and navigation skills at a later stage. As pilot trainees move on to highly automated glass cockpits

and multi-crew systems relatively late in their training, their opportunity to develop non-technical skills such as communication may be limited, due to the focus on automation (Harris, 2009; Dahlstrom et al, 2008).

The automated cockpit leads to blurred lines between technical and non-technical skills. The overall approach of training technical manual flying skills and CRM non-technical skills separately was felt not to reflect the intrinsic relationship of automatic flying skills and CRM on the flight deck. This is often compounded by the limited training time available. They emphasise the need to integrate CRM training throughout flight training, and not treat it as separate to automation (Rigner & Dekker, 2009).

## **4.9 LEADERSHIP AND TEAMWORK**

### **4.9.1 Training Need**

#### **4.9.1.1 Overall flight management**

Effective Leadership and Teamwork is essential for teams to work effectively and coherently together. Leadership and teamwork are key components of TEM and CRM and are therefore a frontline defence against threats and errors. In light of threats this includes managing unexpected events and startle, loss of control events and other elements of non-normal flight. In light of errors (made by the crew) the ability to challenge within the cockpit and the ‘trapping’ of errors is central to manage deviations from procedures and checklists.

### **4.9.2 Content**

Leadership is often incorrectly viewed as being a skill that some naturally have, and some naturally do not. Although personality assessments (such as those used in selection) can identify qualities related to leadership, the impact of personality traits are wide ranging and do not determine development into a successful leader. Tiley and colleagues (2011) found that various factors influence the efficiency of a leader, including their ability to attain and synthesise wide ranging information about subordinate activities, ongoing operations, their own objectives and self-awareness. They also describe good leaders as those who have a strong understanding of the operational context, enabling them to be reflexive to uncertain environmental factors. They suggest that training should provide a variety of scenarios, which incorporate a range of strategic information concerning decision points to best develop these skills.

Team performance has been found to be highly dependent on training that focuses on teamwork KSAs (Tiley et al., 2011). Teams also benefit from being trained and tested together. Lubner (2013) assessed the efficacy of an intensive, simulator based flight training programme where 11 students earned their pilot certificates and instrument ratings with fewer flight hours than the US average. They emphasised the benefits observed from group learning and the camaraderie that came from this, providing a support network. Maintaining the same team throughout training to line operation is an optimistic suggestion, but where possible, for example in recurrent training, efforts should be made to achieve this.

In addition to the flight crew, pilots and first officers operate within a wider team of aviation specialists. Collective training provides trainees experience of working in the wider team of aviation specialists, accurately reflecting a multi-team environment (Georgiou et al., 2013). This needs to include the interpositional knowledge previously discussed in section 4.8.2 to help crew members better understand each other’s mental models and challenges (Littlepage et al., 2013).

Leadership and teamwork are both components of CRM training. However, as described previously, there is little available detail in the literature to advise training designers on what

elements of leadership and team working are addressed within training programmes. This suggests they are no different from the content and approaches recommended in the existing (and quite long standing) guidance on CRM and non-technical skills training.

#### **4.9.3 Delivery**

As before, details of training facilities and materials used to train individual competencies are not available in the literature, it is expected that a combination of ground training and flight simulators would be used.

Additional techniques that could be used to train the non-technical skills such as leadership and teamwork include: computer based training. This should incorporate active practise within classroom learning through using games and role playing exercises as well as scenario simulator training (Kearns, 2008). It is suggested that a computerised system would improve standardisation of CRM training; however, the study does not explicitly define the CRM competencies trained. Additionally, hangar talks can be used for pilots or trainees to discuss unexpected events and how these could have been handled (Kearns & Sutton, 2013). This can be used to inform pilots of error management through vicarious experience.

#### **4.9.4 Instructor Issues**

The skills of leadership are also relevant to instructors, with those showing strong leadership skills achieving higher trainee performance and satisfaction (Tiley et al. 2011). Individual instructor effectiveness has been found crucial to ensuring positive and satisfying pilot training (Holder, 2013). In the Boeing Pilot Experience Survey around half of the pilots interviewed identified that they had had a negative training experience in the past six years. These negative experiences centred on the instructors, including intimidation, perceived knowledge deficiencies and variation in instructor style (Holder, 2013). The authors advise that guidance for instructor qualification and a standardisation of methods through instructor training could address this problem, improving training experience and effectiveness.

#### **4.9.5 Trainee Assessment / Evaluation**

Again, no specific details could be found in the literature regarding the evaluation of leadership and teamwork skills, although they would be included in a standard CRM/non-technical skills assessment, and, therefore, rely on instructor/evaluator judgement.

It is assumed that Leadership skills, in particular, would form a strong element in Command Training and that assessment would be available to address these but no information was found on this.

#### **4.9.6 Training Effectiveness / Transfer**

While there is evidence for the overall training efficacy of CRM training (O'Connor et al, 2008), there is no break down of information on the transfer and effectiveness of the specific skill elements, like Leadership or Teamwork.

Following completion of Type Rating training, trainees will be in the position of first officer until they have gained a substantial amount of experience and can be considered for captaincy. Little information is available on the recurrent training provided to pilots throughout their career and whether this supports the development of Leadership and Teamwork skills to support promotion to the command seat.

#### **4.9.7 Organisational Attitudes**

Organisations may believe that leadership and teamwork skills are intrinsic within their organisation due to the selection of the 'right candidates', hence the attention given to these competences may be less focussed and sustained.

#### 4.9.8 Recognised Gaps

Leadership, Teamwork and Communication become especially important when crews have different cultural or training backgrounds. Given this, it would be expected that more research would be available on training to support multi-cultural working, particularly as airline organisations are increasingly international.



## 5. OTHER AREAS FOR CONSIDERATION

### 5.1 PILOT SELECTION

#### 5.1.1 Rationale

The IATA Guidance Material and Best Practice for Pilot Aptitude Testing (March, 2012) provides information regarding how selection should be managed within training, the main points of the report are:

- ▶ IATA suggests that aptitude testing has proven to be highly effective and efficient.
- ▶ Effective aptitude testing can contribute to significant cost savings to airlines.
- ▶ Training can be tailored to meet the requirements of correctly selected individuals.
- ▶ Increased potential for the airlines' safety culture to be enhanced as a result of a robust and valid testing regime.

Limitations outlined by the report include the lack of detail available regarding aptitude testing for later career phases. Whilst the selection requirements of *ab-initio* pilots are relatively well explored, there is limited detail regarding:

**Ready-entry pilots** – this group (often referred to as 'Direct-Entry') shows various levels of experience. CPL/IR-MPA or MPL license holders with less than 1,000 hours, or with less than 500 hours on a MPA are considered as Ready Entry Pilots with low experience;

**First officers** – type rated with more than 500 hours on MPA;

**Captains** – type rated with successful completion of an operator commander course.

The initial plan for this literature review had been to include a section on selection in the discussion of each of the pilot competence areas in Section 3, in terms of any underlying capabilities and competences that are required to undertake training. However, it became apparent, that the information to support this discussion is limited.

The rationale behind considering selection in a pilot training review is that individuals' underlying capabilities provide the baseline from which all training must begin. With reductions in training time, it may become important to select pilot applications more rigorously in order to ensure the necessary levels of competence can be reached in the training. Furthermore, with increasing complex aircraft systems, the basic skills required of pilots may change. While having effective manual flying is still clearly an essential requirement, in the future greater computing skills may become a requirement.

The information identified is presented in three main ability areas: psychomotor, cognitive and interpersonal. This is limited to recent studies related to the scope of this project. Clearly there is considerable general literature on selection, but the remit of this project did not extend to covering this.

#### 5.1.2 Psychomotor Abilities

Psychomotor abilities refer to the applicant's ability to coordinate cognitive functions and physical movement. These skills are highly relevant to manual handling. Psychomotor abilities have been rated as very relevant in informing decisions of trainee selection (Goeters, Maschke, & Eisfeldt, 2004). These skills are assessed through the use of behavioural exercises, such as simulation based tests, in combination with interviews, questionnaires and psychometric.

### 5.1.3 Cognitive Abilities

Cognitive abilities refer to information processing and thinking skills, e.g. short term memory, spatial awareness, perception, reasoning, and judgment. They are highly relevant to all aviation tasks. A category of cognitive skills, e.g. decision making, situation awareness, tend to be included under CRM, but they are also necessary for flight handling, automation management, emergency response, etc. and so should also be considered in terms of underlying capacity for technical understanding.

There is no requirement for applicants to have an understanding of automation at the point of selection. Selection instead aims to identify the applicants with the capacity to learn the relevant KSAs in training. The specific content of cognitive ability selection tests varies. As well as a trainees' motivation to learn, they must also have the cognitive ability to process complex information to facilitate the learning of pilot job knowledge and skills (De Jong, 2010). Cognitive abilities include short term memory, spatial awareness, perception, reasoning, and judgment.

Carretta (2013) found that the Multidimensional Aptitude Battery (MAB) and MicroCog scores, both assessing cognitive ability, demonstrated predictive validity against most of the training criteria and flight training ability. This demonstrates that pilot performance is affected by both 'can do' factors, such as cognitive ability, and 'will do' factors, motivation. This aspect is covered by selection batteries, with cognitive aptitude tests assessing the 'can do' and job knowledge interviews, personality and previous experience demonstrates a candidates 'will do' approach.

Zierke (2011) conducted a study with 402 student pilots at a major European airline during their theoretical ab-initio training for ATPL. The selection approach contained seven cognitive ability tests (concentration, memory capacity, quantitative ability, and spatial orientation), four knowledge tests and two psychomotor ability tests. It was found that the knowledge tests and recorded school grades were related to success in the Flight School Starter Course more strongly than the cognitive ability tests.

### 5.1.4 Interpersonal Abilities

Interpersonal abilities, such as communication and teamwork, are considered to be a key competency to be focused on in aviation selection (Goeters, et al., 2004). Whilst interpersonal skills can be assessed by interview or during activities at a selection centre, personality and social competence assessments can also provide an insight. The area of interpersonal skills is the area where greatest information was found in the literature.

Personality traits such as extraversion, emotional stability, dominance (leadership), agreeableness and emotional warmth have been found to correlate with social competence (Hoermann and Goerke, 2014). Individuals rated highly on social competence are likely to be successful in CRM and TEM training, due to the overlap of competencies assessed within social competence and the competencies required in CRM/TEM, enabling pilots to develop strong non technical skills.

Hoermann and Goerke (2014) compared questionnaires aimed to assess social competence (skills required for effective team work, including communication) and personality with current assessment centre methods with 292 *ab initio* pilots at a major European airline. Whilst tests from the assessment centre were weak predictors of social competence, the questionnaire was found to be a significant predictor of social competence. This suggests that structured questionnaires may be better at identifying social competence and communication competency than observed behaviour at assessment centres. Current selection techniques should incorporate these questionnaires because evidence suggests that subjective assessments may not be reliable in determining an individual's social competence.

Although the study did not find that social competence predicted success in *ab initio* training this could be because social competence skills become more relevant after *ab initio* training in Type Rating training where trainees are introduced to multi-crew settings, TEM and CRM. This could explain variation observed in the efficiency of CRM and TEM across training groups (O'Connor et al. 2008). The authors suggest that by including measures of social competence as part of selection, pilots will be well placed to benefit from CRM/TEM training, and this will ensure pilots develop strong non-technical skills. Non-technical skills are more relevant in highly automated, advanced aircraft and, therefore, selection techniques should reflect this.

Swauger (2011) surveyed First Officers to establish the characteristics associated with 'airline excellence' in Pilots they had worked with. First officers identified 'personality' as the second highest characteristic after CRM environment. In addition to this, an easy going nature, and sense of humour were also identified and scored highly. Interestingly these qualities were not included in the prompt list within the survey, and were generated by respondents, demonstrating the value placed on these traits, in light of how they foster good team work and provide directed leadership.

## 5.2 SKILL FADE

Recently, concerns have been raised regarding the degradation of commercial pilot handling skills. As the use of glass cockpits and automation has increased, pilots no longer need to use their basic manual flying skills on a regular basis and so this skill will diminish. This is especially relevant on long haul flights, where pilots experience long periods of inactivity, and may get no opportunity to practise manual skills as typically one of the complement of pilots will manage take-off and landing (Rankin, 2012). Current research supports these concerns.

Ebbatson and colleagues (2010) found manual flying performance skills were noticeably rusty. Recent flying experience, rather than flying experience overall, influenced their appropriate use of manual control strategies, indicating that skills fade is a concern for pilots of all experience.

The Significant Seven report encourages the need for pilots to have accrued 10% more flight hours than is currently specified to progress to a type rating course. This additional 10% is focussed on basic handling skills. Although this acknowledges the need for stronger manual flying skills, this contrasts with Ebbatson's (2010) finding that indicates that recent experience supports manual skills maintenance rather than previous experience.

Gillen (2008) assessed advanced glass aircraft pilots' ability to manually fly five basic instrument manoeuvres and also surveyed pilots' perceptions of their skill. It was found that the pilots' manual flying skills were below the requirement for the ATP pilot certification, and this was attributed to lack of recent basic instrument flying experience. Although the pilots felt that their flying skills had degraded over time, they overestimated their basic instrument skill, overestimating their ability to perform manoeuvres.

PARC and CAST (2013) found that although instructors and operators were concerned about manual handling skills deterioration, they were uncertain as to how to encourage retention through operational policies and line practice. Although many airlines support the use of manual skills in routine line flying to mitigate degradation, this study suggests that pilots are unlikely to be aware of their limitations so as to direct their own personal learning. Additionally, manual flying skill training is known to be repetitive (PARC & CAST, 2013), and manual flying skills required in normal flight do not reflect those in emergency situation. Therefore, training should be driven by the carrier and where possible include simulator sessions.

The literature concerning skill fade in aviation focuses on manual flying skills. Although this is clearly a key area of concern, research in other competency areas would be beneficial. For

example, knowledge and skills around use of certain automated systems and recognising certain problem situations. Considerable research has been conducted in the defence community on skill fade in recent years. This has developed to the extent that support tools have been developed to help trainers establish the general rate of skill fade for specific aspects of competence in order to develop more extensive recurrent training schedules (Cahillane & Webb, 2014).

### **5.3 TRAINING WASTAGE**

Training wastage refers to individuals who leave aviation either during or immediately after training. Limited information is available regarding training wastage in the reviewed literature. Although most literature reviewed removed all data related to drop-outs prior to analysis, APCO Insight (2011) found that the perceived value of that training, the quality of the instruction, the sense of student community and the relationship between the student and the instructor were most important for trainee retention, with the cost of training having a minimum impact.

Understanding training wastage would support training evaluation and provide organisationally relevant improvements. For example, training wastage has an impact on throughput, reducing the number of potential pilots in the recruitment pool. Through understanding why trainees are not succeeding, and adapting to their needs where appropriate training could be made more efficient.

### **5.4 DISTANCE LEARNING**

Distance training has become a more popular form of training, in light of the geographical expansion of organisations. Similarly to the modular approach to training, distance learning offers trainees greater flexibility, and therefore benefits the industry through making training more accessible. It also has the potential to be more adaptable to the trainee, allowing them to take longer to complete modules or through training groups of mixed nationality. There is limited evidence available to support the use of distance training (and the ability of trainees to learn at a distance) in aviation. Trends in other areas demonstrate the availability and value of distance learning materials (Kearns, 2008). Distance learning can be combined with learning in virtual environments and it has been suggested that e-learning is well suited to trainees coming from Generation Y to holistic and immersive training practices (Kalbow, 2011).

## 6. CONCLUSIONS

### 6.1 KEY OBSERVATIONS ON THE STATE-OF-THE-ART

#### 6.1.1 New Training Content

A wide range of 'state-of-the-art' training activities can be identified in the published research literature, both in the general training and applying these specifically to the aviation environment to address the known problems in pilot training. Examples of these include:

- ▶ Increase opportunity for manual flying, including in unusual attitudes;
- ▶ Specific training to support upsets recovering, including managing 'startle' through more realistic training environments regarding stress;
- ▶ Increased focus on declarative knowledge on automated systems, including underlying logic to help development of mental models, different modes and their transitions;
- ▶ Integration of technical and non-technical skills related to flight handling;
- ▶ Development of monitoring skills;
- ▶ Training on cues to recognise 'upsets' and lapses in SA;
- ▶ Use of mnemonics for decision making;
- ▶ Development of meta-cognitive skills to support self-evaluation and review;
- ▶ Prioritisation skills and strategies for workload management, including task shedding;
- ▶ Stress management training, including through earlier inclusion of stress in training;
- ▶ Training in human vulnerability regarding procedures, in particular checking/cross-checking;
- ▶ Review of communication barriers associated with cross-cockpit power gradients;
- ▶ Cultural awareness training;
- ▶ More explicit focus on development of leadership/command skills.

Effectively, what needs to be trained appears to be quite widely reported. However, across the board, the information available about exactly how to train the identified knowledge and skills in such a way as to maximise learning is limited. Furthermore, the extent to which these recommendations from the literature are being implemented is not known.

One point to observe is that many, although not all, of these developments have been recognised as important for some time. In some cases, the increasing aircraft automation and the demands from the operational environment may mean further advances and iterations are needed, but in others cases it seems that previous recommendations may not have been implemented in an effective manner (if at all). It may be that the lack of practical guidance on implementation makes it challenging to implement changes. Or broader organisational and regulatory issues could make it difficult to introduce more revolutionary changes. These points can be explored in the stakeholder interviews.

#### 6.1.2 Competence-Based Training

Although not a new development, competence-based approaches to training are increasingly being recognised as valuable in professional domains where 'training time' has previously been the main criteria for reaching assessment gates. They allow the different elements of effective performance to be identified and to be decomposed into the requisite knowledge, skills and

attitudes. Trainees are then assessed against the necessary standards for these, including allowing for different standards to be associated with different levels stages in training. It is difficult to see how this type of approach would not be beneficial in pilot training, which is so safety critical, particularly as it becomes impossible to train for every eventuality possible in a modern cockpit. Similarly, a competence-based approach can be applied to instructor training and assessment. Indeed, it could be argued as even more important for instructors to be competent because it is their assessment of the trainees that lead to them being qualified to graduate from different levels of training. Importantly instructor competences should include those associated with piloting and training/education to cover both elements of their role.

One area where it is not clear if the competency approach has been fully developed in aviation is around the specification of the actual KSAs. The list provided by IATA in the EBT guidance does not distinguish between elements of knowledge, skill and attitudes, which would be helpful to focus training, and it has not integrated technical and non-technical skills. As a result, these different aspects of performance are not described in similar levels of abstraction and the need for a fully integrated syllabus is not made apparent.

### **6.1.3 Resilience**

Resilience is a central feature of real state-of-the-art training. Rather than considering safety issues separately and creating additional training recommendations to address each issue, similarities across safety issues should be considered, and training should focus on training resilient skills and knowledge to enable the pilot to be adaptive to a wide catalogue of situations. By creating a unified approach to safety issues, less pressure is placed on organisations and instructors to incorporate add-ons.

### **6.1.4 Fragmentation**

The current approach to training is fragmented: through time, across skill requirements and when considering associated instructor training requirements. This is likely to be due to its evolution from a modular, time-based system, which has evolved with additional components being added to programmes when they become identified as a training priority. Courses such as MPL offer an integrated route which should mitigate some of these issues, as may approaches such as Evidence-Based Training. However, perhaps due to their recent development, information regarding the effectiveness of these programmes has not yet appeared in the public domain.

### **6.1.5 Integration of Research**

To achieve implementation of the state of the art in operational training, it is crucial that there are organisational pathways that bridge the gap between research and the development of training programme and the day to day training of pilots. For example, literature emphasises the need for CRM training to remain effective and relevant in light of changes in aircraft design, operational conditions, emerging risks and operator demographics (O'Connor et al., 2008; Harris & Li, 2006). In 2006, Salas and colleagues identified a need for CRM training to be informed by training and learning research. They believe that benefits from research are not being fed through to operational delivery and that the training is not fully integrated in organisational activities. As a further example, the FAA first made recommendations about improvements to pilot training to better manage automation and advanced aircraft technology more safety in 1996. Yet in 2015, very similar issues are being identified as a concern and accidents are still occurring. This suggests that something is still not right in the exploitation of research and development work into the actual training and operational environments.

## 6.2 GAPS IDENTIFIED IN REVIEWED LITERATURE

The following areas were recognised as particular gaps in knowledge and information from across the breadth of material reviewed for the study (i.e. from all sections). They arise primarily due to limited availability of specific or detailed information to support training developers implementing the state-of-the-art.

- ▶ Clearly defined, detailed competency frameworks for pilot KSAs;
- ▶ Methods to develop airline specific KSAs;
- ▶ Approaches for systematic needs-based training analysis;
- ▶ Approaches to optimise retention of manual flying skills, including in unusual attitudes;
- ▶ Techniques for stress management training, including introducing more realistic stress to training sessions for stress inoculation;
- ▶ Techniques for metacognitive competency training;
- ▶ Techniques for sensemaking training in aviation;
- ▶ Information on adaptability and flexibility training to improve pilot resilience;
- ▶ Approaches for improving prioritisation and workload management;
- ▶ Information on cross-cultural cockpit communication training;
- ▶ Techniques to overcome cockpit power gradients and reluctance to speak-up;
- ▶ Guidance on integration of technical and non-technical training from the early stage;
- ▶ Guidance on the use of low-cost training tools such as low-identify 'what-if' training and use of computer games;
- ▶ Evaluation of the effectiveness of training courses and programmes along the pilot career pathway.

It may be that some of these topics have already been covered in literature that is more than six years old, in which case might not have been picked up in this literature review unless they have been referenced subsequently. The aviation industry could already also be addressing the gaps but because of such limited publication of results from effectiveness evaluations, this information has not been disseminated. If so any information should be identified during the stakeholder interviews, and if not, then these gaps will be fed forward to be considered at later stages of the project.

## 6.3 TOPICS FOR THE STAKEHOLDER INTERVIEWS

Based on this literature, a number of areas emerge that should be considered in the Stakeholder Interviews to explore how much of the state-of-the-art has transferred to initial and operator training, if any further advances exist that have not been reported in the public domain and to understand the barriers and enablers to changes in the pilot training system.

Important topics include:

- ▶ What training philosophies are adopted?
- ▶ How are competencies/KSAs identified and addressed in training course? What is the balance between areas?
- ▶ Are specific training methods and techniques adopted for different competences and/or elements of competency (e.g. K, S or A)?

- ▶ How is training integrated across the competency areas and career pathway?
- ▶ How are Instructors selected, trained, evaluated and kept appropriately certified?
- ▶ How are training courses and pathways evaluated?
- ▶ What have the latest training developments implemented in the organisation been? How and why were these developed and evaluated?
- ▶ What are the main drivers for change in training strategy and delivery within the organisations?
- ▶ How do regulatory agencies support (or not) implementing training improvements?
- ▶ What are the biggest challenges for the organisations in optimising training?
- ▶ What could be done to help organisations improve training to meet the demands of increasingly advanced aircraft, growth in the volume of air traffic, limited supply of pilots, etc?

These question areas will be developed further to support semi-structured interviews with airlines, helicopter operators and other aviation training-related organisations. The results from the interviews will then be compared to these results to identify gaps with the implemented training programmes, and were gaps in knowledge and technique to support training requirements exist.



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