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FLIGHT CREW TASK PERFORMANCE AND THE REQUIREMENTS FOR A NEW TOOL SUPPORTING THE PRE-FLIGHT, FLIGHT PLANNING AND BRIEFING TASK

Volume I

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FLIGHT CREW TASK PERFORMANCE AND THE REQUIREMENTS FOR A NEW TOOL SUPPORTING THE PRE-FLIGHT, FLIGHT PLANNING AND BRIEFING TASK

Thesis submitted for the Degree of Doctor of Philosophy (Ph.D.),

Department of Psychology,

Trinity College,

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Joan Cahill – November 4 2010

Declarations

This thesis is submitted by the undersigned to Trinity College, University of Dublin, for examination for the degree of Ph.D.

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Thesis Summary

The Flight Crew task involves more than flying the aircraft and interacting with different human agents and tools in accordance with standard operating procedures (SOPs). Rather, the Flight Crew task involves managing different levels of complexity associated with the physical flight environment, the team environment and the broader operational and organisational system. In so doing, the Flight Crew act as a co-ordinating interface between different human agents involved in the Active Flight Operations process and other processes that interface with this process. Central to this, is the management of information. Flight Crew obtain relevant task support information from different team agents and tools to support the individual and collaborative requirements of the process. Specifically, information is used to assess the situation and identify an appropriate course of action. Critically, the quality of tools and information available to Flight Crew both shapes task performance and impinges on task outcomes. However, the nature of the information provided to crew – both in terms of the human computer interaction (HCI) design of task support tools and the information provided by team agents - is determined by the underlying process design.

The pre-flight, flight planning and briefing task plays a key role in terms of Flight Crew management of complexity and the associated co-ordination of information inputs across different team agents and tools. The pre-flight, flight planning and briefing task is also essential in terms of cementing team concepts, supporting team situation awareness and managing workload. Further, this task is important from an operational perspective. The signoff of the Flight Plan is a key step in the operational process. Moreover, this task functions as a key interface between the management of the process by Flight Crew and the wider management of the process by Flight Operations Control.

Yet, several problems related to the execution of this task can be identified. Primarily, this concerns weaknesses in relation to the delivery of relevant operational and safety information to Flight Crew in the existing Flight Plan, weaknesses in the sharing of information between Flight Crew and other agents at the pre-flight stage, and more global weakness in the sharing of safety information across different Flight Operations functions at different points in the Flight Operations process timeline. Also, following from Crew Resource Management (CRM) theory, there is a notion of good practice in briefing. Yet, Flight Crew briefings at the pre-flight stage often fall short of this. Further, Pilots can be complacent about the importance of applying CRM principles in practice. In addition, the introduction of low cost business models has resulted in less time to perform the pre-flight, flight planning and briefing task.

Despite the importance of this task, and the existence of these task problems, there seems little attention on this task. Many new tools have been introduced into commercial cockpits. Nonetheless, to date new tool development in the commercial aviation sphere has not

focussed on ameliorating these task problems and/or making improvements to the Flight Plan.

Many of the problems experienced by Flight Crew at the pre-flight stage can be attributed to process design weaknesses related to the sharing of operational and safety information across relevant team agents at different points in the Flight Operations process timeline. Thus, the delivery of the right information to Flight Crew by means of an improved Flight Plan and the parallel specification of improved Flight Operations processes assisting information flow across team agents at different points in the overall Flight Operations process timeline provides the mechanism in which to resolve Flight Crew task problems at the pre-flight stage. That is, by changing the process and specifically, changing what information is communicated to Flight Crew in the Flight Plan, it is possible to transform the way the task is performed for the better. Thus, the introduction of an enhanced Flight Plan will provide the task and information support necessary to facilitate a more powerful briefing (i.e. good practice in briefing).

An analysis of existing Human Computer Interaction (HCI) methods – both formal and informal, and methods used in the Organisational Ergonomics field (i.e. process mapping), suggests certain requirements for valid methodology to support both the analysis of the task and future system design. Methods must deliver on the analysis of the existing task (including existing process design problems which impinge on the current task), and the specification of the future task and process (taking into account the prior analysis of process design weaknesses and improvement requirements). Moreover, specific design guidance must be provided. In so doing, the proposed tool concept must be prototyped and evaluated. Further, the underlying process requirements necessary to the implementation of the new tool concept must be specified. In addition, implementation barriers must be addressed. An analysis of existing Human Computer Interaction (HCI) methods – both formal and informal, and methods used in the Organisational Ergonomics field (i.e. process mapping), suggests that no one method on its own can deliver on this requirement. Thus, the research design reflects an integration of formal human computer interaction (HCI) methods (i.e. user interviews), Ethnographic methods (i.e. user observation), Participatory Design methods (i.e. envisionment of new task practices/tool requirements and collaborative prototyping and evaluation), and methods used in Organisational Ergonomics field (i.e. process mapping). Overall, three phases of research, spanning six studies were undertaken. Collectively, these deliver on the requirements for a valid methodology as outlined above.

This research has resulted in the definition of a new integrated model of the Flight Crew task performance. In general, the proposed model reflects a shift from a local explanation of Flight Crew task performance to a broader 'process' based explanation. Further, a descriptive account of the pre-flight, flight planning and briefing task is provided. This includes an account of the role of this task in relation to the wider task and specific task

problems. Moreover, this research has led to the specification of the requirements for a good briefing. In support of this, a new tool concept – the Intelligent Flight Plan – has been defined. This new tool concept addresses the requirements for a good briefing. In so doing, it solves the specific process and task problems associated with this task. Further, a preliminary account of the underlying Flight Operations processes necessary to the implementation of this concept at an airline is presented.

It is concluded that the development of an electronic version of the Flight Plan affords the opportunity to rethink the flight plan concept from the perspective of improving information flow across the socio-technical system. The introduction of the proposed Intelligent Flight Plan results in a new way of performing this task and new Flight Operations processes. Specifically, this introduction of a new Flight Plan provides the opportunity to improve the quality and availability of information provided to Flight Crew, thereby enhancing the quality of crew briefings. It is anticipated that the proposed Intelligent Flight Plan will enhance safety through improving system information flow and associated crew situation awareness and assessment. Moreover, in addition to enhancing Flight Crew practice of the pre-flight, flight planning and briefing task, this might have the added benefit of encouraging high involvement and reducing procedural drift.

The overall objective for this research has been to identify and demonstrate a solid concept for an improved Flight Plan. This can be further extended and validated in future research activities. In particular, future research might investigate further issues related to the implementation of the Flight Plan at an airline and the associated process redesign requirements. In addition, future research might investigate the links between the proposed 'Intelligent Flight Plan' concept and recent research in the area of free flight and reduced crew concepts.

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Introduction

1. CHAPTER INTRODUCTION

This chapter presents an introduction to the thesis problem, the theoretical background to the conceptualization of the thesis problem and the associated methodological design of this thesis, and the specific objectives of this thesis. Further, this chapter provides an introduction to the research design and a preview of the six thesis studies.

2. INTRODUCTION TO THESIS PROBLEM

Background to the Problem

Flight Safety

Given traffic growth it is likely that the number of accidents will rise (Group of Personalities, 2001). This is unacceptable for the travelling public. Critically, the accident rate needs to be reduced. To achieve this, airlines must carefully monitor and improve safety levels. This links to a range of activities concerning the specification and management of the airline's safety management system, in accordance with regulatory guidance (ICAO, 2009). Further, airlines must ensure that operational and safety performance is adequately supported. What does this mean from a Flight Crew perspective? Firstly, appropriate crew management processes (i.e. crew training, rostering and licensing) must be in place. Flight Plans must be carefully designed taking into account known operational problems and potential threats. Flight Crew must have the right tools and information to execute the flight. Lastly, airlines must ensure that crew safety practices are properly defined, appropriately supported and adhered to. This includes general flight operations procedures, Crew Resource Management (CRM) procedures, specific crew briefing procedures and reporting procedures.

Flight Crew Task

The Flight Crew task involves more than flying the aircraft and interacting with different human agents and tools, in accordance with standard operating procedures (SOPs). Rather, the Flight Crew task involves managing different levels of complexity associated with the physical flight environment, the team environment and the broader operational and organisational system. In so doing, the Flight Crew act as a co-ordinating interface between different human agents involved in the Active Flight Operations process and other processes that interface with this process. In relation to the latter, this spans other Flight Operations

processes (i.e. Flight Planning and the Safety/Quality/Improvement process), the Air Traffic Management (ATM) process, the Ground Handling process and the Maintenance process.

Flight Crew can be characterized as actively managing/coordinating the process through relevant information management activities. Flight Crew obtain relevant task support information from different team agents and tools. Specifically, information is used to assess the situation and identify an appropriate course of action. Critically, the quality of tools and information available to Flight Crew shapes task performance and impinges on task outcomes. However, the nature of the information provided to crew – both in terms of the human computer interaction (HCI) design of task support tools and the information provided by team agents – is determined by the underlying process design.

Role of the Pre-Flight, Flight Planning and Briefing Task

The pre-flight, flight planning and briefing task is performed at the start of the flight. Depending on the crew location, the task is performed in the crew room or in the aircraft cockpit. Task activities vary according to the nature of the operation (i.e. short range and long range operations). However, in principle, the task involves the review of all flight information, the assessment of flight threats and associated threat management strategies, the assignment of flight roles (i.e. Pilot Flying and Pilot Monitoring) and the signoff of the flight plan.

Critically, the pre-flight, flight planning and briefing task plays a key role in terms of Flight Crew management of the different levels of complexity, and the associated co-ordination of task and information inputs from team agents involved in the Active Flight Operations process, and all processes that interface with it. Further, the quality of Flight Crew task activity at the pre-flight, flight planning and briefing stage, has an impact on Flight Crew task activity more generally. This can be conceptualized both at an operational and safety/human factors level.

Firstly, Flight Crew task activities at the pre-flight, flight planning and briefing stage are important from an operational perspective. As part of task performance, the crew gather and review all information necessary to an assessment of the risk status of the operation and any required changes to the Flight Plan (i.e. fuel figure and routing). This necessitates interacting with relevant people involved in the same and different processes. As such, this task plays a key role in relation to Flight Crew coordination/management of the process. The signoff of the Flight Plan is also a key step in the operational process. Without an agreed routing and fuel figure the process cannot commence. Thus, this task delivers specific process requirements in relation to the signoff of the flight plan. Moreover, the decision to go with the existing Flight Plan or to request changes (i.e. changes to the proposed routing and alternates and/or requests for additional fuel) is significant from a broader operations management perspective. Changes to the Flight Plan at this early point in the process have

little operational impact and are relatively easy to manage. However, the late identification of such changes (i.e. during cruise and/or during the descent, approach and landing phase) has a significant operational impact. For example, this might result in the requirement to divert to an alternate, which has implications both for the existing flight (i.e. delivery of passengers to final destination), and for subsequent flights (i.e. aircraft changes and delays). In addition, these issues are more difficult to manage at this time. In this way, the pre-flight, flight planning and briefing task functions as a key interface between the management of the process by Flight Crew, and the wider management of the process by Flight Operations Control/the Duty Manager.

The performance of the briefing task is also critical from a safety/human factors perspective. Here, we must consider the significance of this task, in relation to promoting situation assessment and teamwork, managing complexity and managing workload.

Overall, a safe flight starts with effective performance of the pre-flight flight planning and briefing task. As part of the briefing, the crew review and assess all known threats. This situation picture forms the basis of crew decision making in relation to approving or suggesting changes to the Flight Plan. In this way, the performance of the briefing task contributes to the assessment of the flight situation and decision making in relation to this assessment. This helps mitigate two major ways in which errors arise – namely the assessment of the flight situation and allied decision making - as proposed by Orasanu, Dismukes and Fischer (1993).

The briefing task is also essential in terms of fostering team concepts and supporting effective crew communication and joint decision making. As reported by Bennett (2006), co-operative behaviour, cohesion and co-ordination promote safety. This is essential in the low cost environment, where crews may be meeting for the first time, and/or there can be many crew changes. Poor crew resource management has been cited as a key contributory factor in a large number of accidents, specifically the Tenerife Accident (CIAIAC A -103, 1977). Significantly, the analysis of the accident literature suggests that *"Most safe and accident-free flights are the direct result of CRM"* (Krause, 1996).

In addition, this task is also important from a workload management perspective. If the crew is well briefed at this early stage, then it is more likely that they will be able to handle increased levels of operational and environmental complexity, along with an increase in workload, if the situation changes.

Thesis Problem

Introduction

Primarily, the thesis addresses the requirement to introduce a new Flight Plan which will resolve some of the problems concerning Flight Crew execution of the pre-flight, flight planning and briefing task as outlined previously. This thesis also addresses a further issue broadly related to this first problem. This includes system information flow problems arising from the design of the existing Flight Operations process which have an impact on Flight Crew task activities at the pre-flight stage.

Problems Associated with the Pre-Flight, Flight Planning & Briefing Task

As noted above, the pre-flight, flight planning and briefing task is important both from an operational and safety perspective. However, a number of problems related to Flight Crew execution of this task can be identified. Often, the execution of the pre-flight, flight planning and briefing task does not follow best practice in briefing as defined in airline CRM procedures. Typically, a minimum briefing is performed. Although the operational outcome is achieved (i.e. identification of fuel requirements taking into account routing, weather and aircraft technical parameters), key safety/human factors task outputs such as the development of a team concept and joint situation awareness are not always achieved and/or not always optimally achieved. This relates to the larger problem of procedural/operational drift (Helmreich, Klinect, and Wilhelm, 2001; Helmreich, Klinect, Wilhelm and Merritt, 2001). In general, this problem is attributed to Pilot complacency (Helmreich et al, 2001). However, Losa (2007) offers an alternative explanation. For Losa (2007), the broader operational and organisational environment often makes it difficult for Pilots to follow procedures. In support of this, Losa (2007) cites problems related to the design of existing Flight Operations processes concerning the sharing of both operational and safety information, which impact on Flight Crew task performance. Further, Loukopoulos, Dismukes and Barshi (2003) observe that different levels of operational complexity can make it difficult for Flight Crew to follow procedures as defined in airline SOPs.

The briefing task is not well supported in terms of the quality and availability of information provided to Flight Crew in the existing Flight Plan. Currently, the Flight Plan does not provide a summary overview of key operational information. Accordingly, the crew must gather and integrate data across a range of paper based and/or electronic tools, to form a high level overview of the flight situation. Further, there are many gaps in the information picture provided. The Flight Plan does not feature real-time operational information. Consequently, the crew spend much time 'pulling' this information from relevant operational roles. Valuable

time is wasted gathering information, as opposed to analysing the implications of the information picture from an operational and safety perspective. In certain cases, some of the information provided in the Flight Plan is not very detailed (i.e. fuel information and information about the technical status of the aircraft). Also, the Flight Plan is not integrated with broader airline SMS processes. Crucially, the Flight Plan does not provide crew with an assessment of the risk status of the operation and associated flight specific threats/risks information. Further, the existing Flight Plan does not support broader Crew Resource Management (CRM) activities.

Many new tools have been introduced into commercial cockpits. New cockpit tools are being developed to improve cockpit information management and ground/air communications. Tools have been advanced to enhance crew situation awareness (Solodilova I, Lintern G, and Johnston N, 2003, Solodilova and Johnson, 2004), facilitate aircraft navigation guidance and control tasks (Doherty and Wickens, 2001; Theunissen, 1998) and provide assistance in terms of task/workload management (Funk, 1999). Further, new operational concepts are being introduced to solve broader operational problems linked to the design of the existing flight operations concept. This has resulted in the advancement of new cockpit tools facilitating Flight Crew 4 D trajectory management (Johnson, Battiste & Bochow, 1999), along with new technologies facilitating information sharing across the different stakeholders involved in the operation (i.e. Flight Crew, ATC and airport operator). Nonetheless, to date new tool development has not focussed on making improvements to the existing Flight Plan and/or ameliorating the task problems outlined previously.

Reductions in aircraft turnaround times, following the movement towards low cost business models, have resulted in less time for briefing. Moreover, the movement towards low cost operations has put a more general strain on Flight Crew. In short haul operations, the crew may fly multiple routes in one day. Some of these sectors may involve crew and aircraft changes. Flight Crew duty times have been extended albeit within the legal limits. Work days are more intensive and crews are periodically fatigued. In this environment, the requirement to support pre-flight briefing activities is even greater.

Wider Process Design Problems

Some of the task problems experienced by Flight Crew at the pre-flight stage arise given certain wider problems with the design of the existing Flight Operations process. Primarily, this concerns the design of Flight Operations processes related to the sharing of both operational and safety information across relevant agents, at different points in the Flight Operations process. In particular, this concerns weaknesses in information sharing procedures across relevant Flight Operations functions at the pre-flight stage, and weaknesses in the provision of safety feedback from Safety/Risk functions to Flight Planning, Dispatch, Flight Operations Control and Flight Crew.

3. UNDERLYING THEORETICAL & METHODOLOGICAL FRAMEWORKS

Introduction

Both the socio-technical systems literature and the HCI literature provide a range of theories relevant to a conceptualization of the Flight Crew task problem and how this might be resolved. Further, this literature provides the conceptual foundation for the selection of methods supporting the analysis of Flight Crew task activity and the design of new systems to solve specific task problems. Overall, this literature can be analysed in terms of two related themes. This includes (1) understanding task activity and (2) modelling future systems. These are discussed below. However, before doing so, a basic definition of tools/systems is first provided.

Introduction to Tools/Systems

Operator task performance typically involves the use of tools. A tool can be defined as a thing (concrete or abstract) that supports task performance either directly indirectly. This includes paper based information resources (i.e. paper based descriptions of a task or procedure) and machines/systems (i.e. mechanical machines, simple computer systems and complex computer systems).

Tools provide task support at different levels. This can involve providing information to the operator/user which is necessary or relevant to task performance. Or, it can involve performing specific task functions. It should be noted that tools/systems are not the exclusive source of information for operators/users. Information is also provided by other human operators and the environment.

Tools can support full or part-task performance. This depends on the nature/complexity of the task and the specific tool design. In general, simple tasks tend to be supported by stand-alone tools. The performance of more complex tasks often requires that operators interact with a range of tools.

The term 'IT System' or 'Technology' denotes a specific sub-set of workplace tools which are computerized. That is, electronic or computer equipment (both software and hardware) used by different operational roles, to perform specific work tasks which are necessary to the achievement of the operational goal. Workplace IT systems can vary from basic stand alone software applications, to complex computer systems containing many related subsystems used in process environments. Typically, the technology/IT systems used in socio-technical

systems features different levels of automation. Critically, the technology can perform tasks independent of operator/user commands.

Understanding Task Activity

Introduction

A model of task activity must provide a sufficient explanation of task activity. However, this raises several theoretical questions concerning the (1) nature and scope of task activity and (2) what elements of task activity must be considered in relation to the design of new computer systems.

Classic HCI approaches such as Cognitive Task Analysis are derived from specific information processing models of cognitive activity, as advanced in the fields of Cognitive Psychology and Cognitive Science. In general, these approaches focus on modelling the information flow relationship between the person and the machine (Kirwan and Ainsworth, 1992; Crandall, Klein and Hoffman, 2006). In this way, they focus on individual cognitive acts. However, several problems with these approaches have been identified. It is argued that classic HCI approaches fail to provide an explanation of the broader socio-technical dimensions of task performance. This includes an explanation of the shaping influence of the process, teamwork, the environment and tools/information on task activity. This results in a narrow view of operator task activity. Moreover, this impacts on the definition of new technology requirements. Arguably, the definition of tool requirements is limited by the weaknesses in the underlying task model. The theoretical frameworks underpinning these criticisms advance from the human information processing models proposed in the Cognitive Psychology domain. Further, these frameworks broadly link to socio-technical systems theory. Thus, before explaining the particular criticisms levelled against classic HCI approaches, an introduction to socio-technical systems and socio-technical systems theory is first provided.

Introduction to Socio-technical Systems

The term 'socio-technical' refers to the interconnectedness between the social and technical aspects of an organisation. In place of a formal definition of socio technical systems, a range of characteristics to describe such systems have been proposed (Woods, 1988). According to Woods, this list of characteristics is intended to be broad enough to subsume the different types of complexity found in these systems (1988). Characteristics include: large problem spaces, social, heterogeneous perspectives, distributed, dynamic, potentially high hazards, many coupled subsystems, automated, uncertain data, mediated interaction via computers and disturbances (Woods, 1988).

Several qualitative models of socio-technical systems have been provided. The SHEL model (Edwards, 1972, Hawkins, 1987) depicts socio-technical systems in terms of four overall components; software, hardware, the environment and liveware (i.e. humans). Smith and Carayon (1989) propose five overall work system elements. This includes individuals, tasks, tools and technologies, physical environment and organizational conditions. Wilson's model (2000) distinguishes the different elements of the system that people interact with. This includes: other people, agents, organisation, supply chain, environment, task, hardware, software and society. In this respect, Wilson characterizes different types of interactions (e.g. team interactions and interface interactions). Hendrick and Kleiner (2001) and Kleiner (2004) categorise different types of work systems and subsystems. This includes personal sub-system, technological sub system, internal environment, external environment and task/organization design. Rasmussen (2000) provides a vertical model of socio-technical systems. Rasmussen distinguishes the work performed by the operators, the staff involved in planning the work, the management who plan operations and supply resources, the company, the regulators and the government. In similar terms, Moray (2000) describes socio-technical systems in terms of a hierarchy of system layers. This includes individual, team, organization and management, legal and regulatory, and societal and cultural. Critically, Moray (2000) contends that in socio-technical systems, the individual forms the central layer.

Background to Socio-technical Systems Theory

Socio technical Systems theory has it origins in a range of frameworks including Activity Theory (Rubinshtein, 1959), Socio-Technical Theory (Trist and Bamforth, 195) and General Systems Theory (Bertalanffy, 1968).

Activity Theory was developed by the Russian psychologist Vygotsky in the nineteen twenties and later extended by Rubinshtein (1959), Leont'ev (1978) and Luria (1976). Central to this theory is the proposition that human activities are mediated through the use of culturally established instruments. These include language, procedures and tools. Further, this theory holds that human activity is mediated though social interaction. For this reason, activity theorists contend that the analysis of human performance necessitates an understanding of the social, cultural and technical mediation of human activity.

Socio technical theory has its foundations in research conducted by Trist and Bamforth (1951) at the Tavistock Institute in London, relating to the introduction of new technologies and processes in the coal mining industry. The authors argue that a work process cannot be represented either as a technical system (i.e. plant and machinery), or as a social system (i.e. social relations and work organization). Rather it must be conceptualized in relation to both dimensions which are conceived as inter-related (Trist and Bamforth, 1951). Trist and Bamforth (1951) propose two overall principles in relation to socio-technical systems and

their design. Firstly, the interaction of social and technical aspects of an organisation creates the conditions for successful or unsuccessful performance. In all operations this interaction is characterized by a mix of both linear (i.e. cause and effect) and non linear (i.e. complex, unpredictable) relationships. Secondly, the optimisation of each aspect alone tends to increase the quantity of unpredictability in the system. Given this, it is argued that process design is premised on the joint optimisation of both socio and technical factors.

General Systems Theory originates in the research of Bertalanffy (1968). Instead of reducing an entity to the properties of its parts or elements, systems theory focuses on the arrangement of its parts, and the relationship between the different parts that form a whole. This theory holds that a system can be defined in relation to its parts and processes. Different parts of a system have both functional and structural relationships. According to Bertalanffy (1968), systems function in common ways. Chiefly, there is a transformation of an input into an output. Underlying systems theory is a distinction between open and closed systems. A closed system has no exchange with its environment. Contrastingly an open system exchanges matter and energy with its environment.

Socio-technical Systems Theory

Introduction

Socio-technical systems theory provides an explanation of how the different elements of the socio-technical system relate in order to deliver specific operational and organisational goals (i.e. a safe flight). Primarily, these theories provide an explanation of the supporting and shaping influence of different socio-technical elements (i.e. the environment, process and tools/information) on task activity. Collectively, these theories provide an explanation that goes beyond the individual mind. Cognitive activities are conceived of as embodied and situated in specific human and cultural contexts. In so doing, these theories point to particular weaknesses in the cognitive/classic HCI approach. Further, they indicate particular methodological requirements, necessary to the advancement of a valid task model.

Requirement to Understand Role of Environment & Wider Collaborative Activity

Ethnographers argue that classical HCI methods fail to address the role of the environment in terms of shaping task performance. For Rasmussen (1986), the work environment determines to a large extent both operator constraints and the ability of the operator to choose his/her own strategy. In similar terms, Vicente (1999) argues that human skill, knowledge and flexibility are required in the operation of complex systems in unpredictable and dynamic environments. Thus, to understand work demands, both cognitive and environmental constraints must be considered.

Proponents of the Computer Supported Cooperative Work Framework (GSCW) argue that cognitive approaches are insufficient, insofar as they fail to address the wider

collaborative/social aspects of work, which underpin operator task activity (Bannon, L., 1991; Bannon, L., 1993; Bannon, L. 1998; Bannon, L., & Schmidt, K, 1991; Grief, I., 1988). It is argued that human action involves more than what is cognitive. Rather, it includes individual motivation, membership in a community of workers, inter-subjectivity and the actual work setting (i.e. environment). Further, Bannon (1991) argues that collaborative activities and their coordination can be supported by means of the design of human friendly computer systems. Thus, methods need to elucidate team relations and the use of computer systems in terms of facilitating teamwork.

Requirement to understand the shaping influence of process design on operator task performance

In McDonald's analysis, the above methods do not go far enough (2005; 2006). For McDonald, it is also necessary to understand the shaping influence of the process on operator task activity. It is argued that task performance can be both supported and/or constrained by the design of the process. Therefore to understand task performance, we must understand the process and task dependencies which underpin it. Further and following from this, to improve task activities we must first address the underlying process design issues which impinge on task performance (2006). That is, by changing the relationships in the system (i.e. process and task relationships), we have an opportunity to transform task activity.

For McDonald, this necessitates the advancement of a process model (2005; 2006). A valid model should elucidate process and task dependencies and in particular, the collaborative work requirements of the process. Crucially, such a model should make explicit the characteristics and mechanisms of the social process which supports the functional process and the information flow rules inherent in this. In explaining this, McDonald (2005; 2006) distinguishes two related aspects of the operational process. This includes the functional process and the social process. The functional process refers to the transformation of inputs into outputs. The social process refers to the relationship between different system operators. This includes communication and co-ordination mechanisms and informal task activities. McDonald (2006) and Morrison (2007; 2009) argue that the quality of social relations has an impact on the overall operational outcome. Critically, the quality of social relations contributes to the stability of the system (McDonald, 2006; Morrison 2007; Morrison 2009). Therefore, to be successful, the process design (and the related design of tools) must optimise these underlying 'social process' mechanisms.

From a methodological perspective, this creates a requirement for process modelling. The objective of such an approach is to understand how the current process functions and associated social process problems (including information/information flow problems), so that improvements can be identified. Recommendations/changes typically span several

system dimensions, including process design, information flow design, task design and tool design. Ideally, such changes lead to improvements to operational safety, quality and/or productivity. Critical to this, is the production of a diagrammatic representation of the overall process at different levels and the associated process and task dependencies. This includes a representation of the sequential and parallel task activities of all actors which collectively result in the achievement of the operational goal. Underlying this visual map is an analysis of the process as a functional system and as a social system (McDonald, 2006). These approaches have been successfully utilized by Morrison (2007; 2009) in relation to the identification of new technology requirements supporting improved Line and Base Maintenance processes.

Role of Tools and Information

Other theories focus on the role of tools and information in terms of shaping and supporting task activity. The theory of 'Distributed Cognition' investigates certain aspects of the man machine relationship in socio-technical contexts (Hutchins, 1995a, 1995b, Hutchins & Klausen, 1996). Overall, this approach follows from activity theory (Vygotsky, 1978, Rubinstein, 1959, Leont'ev, 1978 & Luria 1976). It is argued that cognitive activity is constructed from both internal (i.e. cognitive acts) and external resources (Hutchins, 1995a, 1995b). In relation to the latter, this includes social interaction with others, interaction with artefacts/tools, and interaction with the environment. Thus, methods must elucidate how information is shared between people, tools and the environment.

Norman's External Cognition theory (1988, 1993) focuses on how the HCI design of tools shapes task performance. For Norman, the form of representation most appropriate for an artefact depends upon the task to be performed. *"With the appropriate choice of representation, hard tasks become easy"*. In this analysis, artefacts don't change our cognitive abilities; they change the tasks we do.

Proponents of the Computer Supported Cooperative Work Framework (GSCW) argue that the provision of task support in relation to information sharing is necessary to support collaborative work. In particular, it is argued that computer tools can be designed to optimise information sharing across all relevant team actors (Bannon, L., 1991; Bannon, L., 1993; Bannon, L. 1998; Bannon, L., & Schmidt, K, 1991; Grief, I., 1988).

Other theorists focus on the role and use of information in socio-technical contexts. Endsley's theory of situation awareness (1988, 1995a, 1995b, 1999a, 1999b, 2000) provides a knowledge oriented interpretation of socio-technical systems. This theory holds that knowledge constantly evolves (Endsley, 1988, 1995a, 1995b, 1999a, 1999b, 2000). By implication, information is critical for the reliability of socio-technical systems.

Losee (1997) contends that information is interpreted situationally and therefore is not neutral. The receiver puts their own meaning on the information, based on their own mental

models of the situation and what is being communicated. Brown and Dugiud (2000) observe how the communication process itself has an impact on meaning. Using the example of news dissemination, Brown and Dugiud (2000) demonstrate how information flows through social channels and that this process shapes how we perceive, interpret and use information. Clark (1996) refers to the participatory act of recognising meaning. It is argued that communication is the joint activity of signalling (both verbal and performed), and the recognition that this must be coordinated through common ground and shared understanding (Clark, 1996). Thus, as proposed by Clark (1996), methods must support the analysis of the nature of interaction between the sender and the recipient, and not just the message being sent.

Others focus on the particular information dimensions underpinning the HCI design of tools which either support or impede task performance. The basic distinction between data and information (Ackoff, 1989) has been used to explain aspects of the HCI problem. Data refers to the raw material for information processing. Information refers to data that has been processed such at it is meaningful to the person (i.e. data that has been interpreted). Knowledge is defined as information acquired through implicit or explicit learning means and in the process combined with experience, context, interpretation and reflection (Davenport and Prusak, 1998). It is suggested that problems arise if there is too much data and not enough information (Wurman, 2001). According to Wurman (2001) task performance is impeded by the provision of too much information. In Wurman's analysis, too much information or 'information overload' serves to distract the user from the critical information (2001). Accordingly, interaction design should prioritise the primary information needs of the end user.

Wilson (1999) argues that the design of a user interface can impact on the strategies used to obtain or access information. Depending on the design execution, it can be more or less easy to obtain the relevant information.

In addition, research has also focussed on the benefits of information visualization in terms of simplifying the representation of large amounts or complex data/information (Card, Mackinlay & Schneiderman, 1999).

Understanding Actual Task Activity

Several theorists focus on the gap between procedures and practice, and the allied requirement to use methods which capture information about real world task activity. An analysis of operator task performance in the maintenance industry indicates that task practice often falls short of operational process descriptions and/or standard operating procedures (McDonald, 1999, McDonald, Corrigan and Ward, 2002). As shown by the authors, normal practice involves 'informal workarounds' which deviate from the formal process and/or are not defined in SOP. In this respect, the formal system (i.e. SOPs) and

normal practice is differentiated (McDonald, 1999, McDonald, Corrigan and Ward, 2002). In similar terms, Sachs (1995) contrasts what she calls the organizational or explicit view of work with the activity oriented or tacit view. According to Sachs (1995), all work contains both explicit (i.e. set of tasks or operations that can be defined) and tacit elements (i.e. workarounds to bypass the problematic limitations imposed by the system).

The suitability of interview methods in terms of delivering on the above requirements (i.e. capturing information about role of environment and real world task practise) has been questioned by Hutchins (1995a). It is argued that interview feedback may not provide a true or accurate picture of the actual work reality. This is specifically the case in regard to task operations that involve collaboration with different operational roles, and where the operational and environmental context shapes operator task workflows and performance requirements. Thus, Hutchins proposes the use of participant observation. For Hutchins (1995a), it is through Ethnography that we gain knowledge about how a distributed system actually works.

Designing Future Systems

Introduction

Much of the HCI literature is dedicated to an analysis of the HCI design process. There is considerable variation in the theoretical frameworks and allied methodological approaches suggested. Broadly two sets of approaches can be distinguished. This includes formal approaches (i.e. classic HCI approaches) and informal approaches (i.e. Participatory Design). These different approaches reflect different theoretical assumptions about (1) the role of end users, (2) the relationship between requirements, design and evaluation, and (3), the degree to which models of the existing task can be used to inform the identification of new tool requirements. These themes are discussed below. Further, an analysis of the HCI literature suggests certain gaps in relation to the scope of the user centred design process. Specifically, this concerns the specification of the process requirements underpinning the HCI tool concept, and the analysis of implementation barriers. This is also discussed below.

Design Process & Role of Users

According to HCI theorists, the design of human friendly technology involves adopting a *'user centered design'* approach (Preece, 2002; Constantine and Lockwood, 1999; Hackos and Reddish, 1998). This is characterized by the involvement of end users at specific points in the design and evaluation lifecycle. Typically, users are first involved at the requirements gathering stage. A user and task analysis is performed to understand how the task is currently performed, and user requirements for either new and/or improved task support tools. Several analysis steps are then undertaken without the participation of end users. This

is followed by different design activities such as storyboarding and prototyping. Once the prototype is developed, users are involved again for the purpose of evaluating the proposed prototype. This usually takes the form of a user test (Rubin, 1994).

Participatory theorists have levelled many criticisms against these approaches. Formal approaches have been characterized as reflecting a 'design for', as opposed to a 'design with' philosophy. Central to Participatory Design theory is the idea that Usability Engineers design 'with' end users, as opposed to 'for' them. Accordingly, users are conceived as active participants in the design process (Bannon and Bødker, 1991; Bødker and Grønbæk, 1996). Further, user participation spans the entire design lifecycle.

Requirements gathering/task analysis, design and evaluation linked.

Participatory design theorists have also questioned the separation between requirements gathering, design and evaluation in formal methods (Bødker and Buur, 2002). According to Bødker and Buur (2002), these activities are linked. It is argued that the requirements gathering process necessitates some level of future tool envisionment and prototyping. To understand this, we must first understand participatory ideas concerning the scope of task analysis. This is explained in more detail below. Further, it is argued that evaluation is implicit in envisionment of new tool concepts. Participatory theorists have also challenged the instructiveness of traditional user and task analysis outputs for design guidance. It is argued that these outputs (i.e. lists of end users, user and task matrices, task workflow diagrams and design briefs), fail to adequately support the design process. Rather, more concrete instruction is required. As highlighted by Carroll (1995; 1997; 2000) design is supported by the development and specification of future use scenarios. This is also discussed in more detail below.

Design not bounded by an understanding of the present task

Central to formal approaches is the advancement of a model of the existing task, for the purpose of specifying future tool requirements (Dix et al, 2003; Norman, 1988; Preece, Rogers & Sharp, 2002). Typically, structured or semi-structured interviews are used to understand and evaluate current work practices and supporting technology requirements (Hackos and Redish, 1998). As defined by Kirwan and Ainsworth (1992), a task analysis *"is a method of describing what an operator is required to do, in terms of actions or cognitive processes, to achieve a system goal"*.

In opposition to this, participatory theorists argue that design should not be bounded by an understanding of present task. Rather, we must also consider the opportunity afforded by new technology to change/improve existing processes and task practices (Bødker, S. & Burr, J. 2002; Carroll, 1995, 2000; Muller 1991, 1993, 2003). Critically, new tool concepts should represent an improvement on the existing situation. In this respect, Bodker et al., (1991)

refer to the paradox of design. *"On the one hand, design must be firmly rooted in work practices of both users and designers. On the other, it must confront these practices with their existing shortcomings and introduce new artefacts such as mock-ups, prototypes, or metaphors, and potentially cause breakdowns. This is how we may learn to transcend our own traditions as users and as Designers"* (Bodker, Greenbaum, and Kyng, 1991).Thus, design teams must envision and evaluate future workplace practices and related technologies, without the constraints of current practice. For participatory theorists, this creates a requirement for future task/tool envisionment. Several techniques are proposed. This includes concept generation, envisionment exercises, scenario role playing, story collecting and story telling (through text, photography and drama), and the co-creation and evaluation of prototypes. Of significance is Muller's PICTIVE technique (1991; 1993) and Carroll's scenario based design approach (1995; 1997; 2000).

In Muller's technique, users actively participate in the design of the user interface. Typically, users mock up a design (either individually or collectively) using basic materials (i.e. pencil, markers and paper), with the assistance of Usability Engineers and/or Designers. The mock up (or prototype) is modified repeatedly for a specific time period, until a design consensus is reached. Often, the session is videoed to record the specific design iterations and the rationale behind proposed changes. As demonstrated in Muller's research (1991; 1993), this technique helps to bridge the gap between the identification of tool requirements and the mapping of interface design features.

Carroll's scenario based design approach (1995; 2000) distinguishes the development of existing task scenarios (describing current practice), and future task scenarios (describing future task practice). In Carroll's analysis (1995), future use scenarios are narrative descriptions of a future task state. This relates to the Participatory Design technique of imagining future work processes and supporting technology requirements. In support of this, Carroll refers to the concept of the task artefact lifecycle (2000). According to Carroll (2000), task outcomes and human experiences implicitly set the agenda for new technological artefacts, which alter subsequent task outcomes and experiences. Therefore design concepts must be envisioned and evaluated in terms of their impacts on human activity, before they are developed. For Carroll (2000), if technology is modelled on existing task practices (i.e. model what is); the technology is fated to being 'one step behind'.

It is argued that new task/tool envisionment necessitates the specification and evaluation of prototypes. As argued by Bannon (1991), users need to have the experience of being in the future use situation, or an approximation of it, in order to be able to comment on the advantages and disadvantages of the proposed system. Thus, some form of mock-up or prototype needs to be built in order to let users know what the future use situation might be (Bannon, 1991; Bannon and Bødker, 1991).

Crucially, the envisionment and weighting of design solutions requires an understanding of actual work tasks and contexts. In this regard, ecological criticisms have been levelled at Participatory Design methods. As defined, these methods do not involve the study of actual task practice/technology usage in real work environments. Although this is an obvious criticism, it is nonetheless important. HCI researchers cannot rely on participant descriptions of practice and associated problems alone. For this reason, ethnographic research is a necessary first step.

Gaps

Certain gaps in the HCI process descriptions can be identified. The introduction of new tools will result in changes at both a process design and a task design level. These new processes and task requirements must be specified. Further, the introduction of new work processes may not be possible. Development costs may be too high. Proposed solutions may raise complex technical issues. Trade offs may be required. As such, the feasibility of the proposed HCI solution must be assessed. Therefore, methods must facilitate the mapping of the underlying processes supporting the implementation of the proposed HCI tool concept, along with reviewing the feasibility of the proposed HCI tool concept and allied process specification. The HCI literature does not provide guidance for either of these activities. In many ways, this falls out of the scope of HCI, as currently conceived.

4. CONCEPTUALISING THE THESIS PROBLEM & RESEARCH OBJECTIVES

The analysis of both the socio-technical systems literature and the HCI literature has implications for the conceptualisation of the thesis problem and how it might be resolved. Following from the frameworks analysed previously, it is argued that the thesis problem and its resolution can be conceptualised both from a HCI and a process design perspective. Specifically, the thesis problem concerns both the HCI design of the existing Flight Plan (and in particular, the information provided to Flight Crew in the Flight Plan), along with the process design rules inherent in the sharing of operational and safety information across team agents and tools, at different points in the Flight Operations process, to support the individual and collaborative task requirements of the process.

The process has a shaping influence on operator task activity on a number of levels. This includes the time allocated to the task, the specification of Flight Crew collaboration/communication requirements with other agents at different points in the process and associated information flow rules, and the delivery of task information to Flight Crew at set points in the process via these team agents and/or task support tools.

Flight Crew obtain relevant task support information from different team agents and tools. Specifically, the information provided by team members and tools forms the basis of Flight Crew situation assessment and decision making activities. This in turn has an impact on the safe achievement of the operational goal. Critically, the quality of tools and information available to Flight Crew shapes task performance and impinges on task outcomes. However, the nature of the information provided to crew – both in terms of the human computer interaction (HCI) design of task support tools and the information provided by team agents – is determined by the underlying process design.

New tools can be introduced to provide the right information to Flight Crew, at the right time – thereby correcting weaknesses in the existing process design. However, this depends on the specification and implementation of new Flight Operations processes. Thus, the delivery of information by means of the specification of both an improved Flight Plan and improved Flight Operations processes provides the mechanism in which to resolve Flight Crew task problems. That is, by changing the process and specifically changing what information is communicated to Flight Crew in terms of the introduction of an improved Flight Plan, it is possible to transform the way the task is performed.

Thus, the resolution of Flight Crew problems related to the execution of the pre-flight, flight planning and briefing task will necessitate a detailed investigation of the existing task and the particular task issues as outlined earlier. Further, it will involve the envisionment of a future improved task, taking into account existing process design problems and potential process redesign solutions. To this end, this research focuses on identifying the requirements for a new electronic Flight Plan embedded in the Flight Operations process.

The introduction of new tools supporting Flight Crew briefing at the pre-flight stage has implications both in terms of the design of Flight Operations processes, and the requirements for new tools/systems for use by other socio-technical agents. In this regard, the primary focus of this research is on the HCI design of tools assisting Flight Crew performance of the pre-flight, flight planning and briefing task.

5. RESEARCH DESIGN

Introduction

An analysis of existing Human Computer Interaction (HCI) methods – both formal and informal, and methods used in the Organisational Ergonomics field (i.e. process mapping), suggests certain requirements for valid methodology to support both the analysis of the Flight Crew task and future system design. To design tools that improve upon current practice, we must start from current practice. As part of this, we must elucidate the relationship between task and process, the team task performance requirements of the

process, the role of the environment in shaping task performance, the impact of context on task performance, and the use of tools and information in shaping task performance. Further, we must capture information about actual task practice as opposed to relying on normative task descriptions. Nonetheless, the introduction of new technology provides the opportunity to change the way the task is performed for the better. Thus, methods must support the envisionment of a future task and associated future Flight Operations processes, predicated on the introduction of new task transforming tools. Critical here, is the use of collaborative prototyping and evaluation techniques to support the envisionment, specification and evaluation of future task practices and allied HCI tool concepts. Further, the introduction of new tools assisting Flight Crew task performance at the pre-flight stage provides an opportunity to resolve existing process design problems which impinge on Flight Crew at this time. In this way, future tool concepts must be envisioned and evaluated in the context of existing Flight Operations process design problems and potential process re-design requirements. Thus, methods, must deliver on the analysis of the existing task (including existing process design problems which impinge on the current task) and the specification of the future task and process (taking into account the prior analysis of process design weaknesses and improvement requirements). Moreover, the specification of a future task and allied HCI tool concepts does not end here. In keeping with participatory approaches, specific design guidance must be provided. In so doing, the proposed tool concept must be prototyped and evaluated. In addition, the underlying process requirements necessary to the implementation of the new tool concept must be considered. Also, implementation barriers must be addressed.

An analysis of existing Human Computer Interaction (HCI) methods – both formal and informal, and methods used in the Organisational Ergonomics field (i.e. process mapping), suggests that no one method on its own can deliver on this requirement. Further, as shown, there are gaps in relation to existing methods in terms of the specification of new processes underpinning the HCI design of new tools and in relation to assessing implementation barriers. Thus, an integration of existing methods along with the adaptation of existing Participatory Design methods for the purpose of new process specification and the assessment of implementation barriers is required. To this end, the research design reflects an integration of formal human computer interaction (HCI) methods (i.e. user interviews), Ethnographic methods (i.e. user observation), Participatory Design methods (i.e. envisionment of new task practices/tool requirements and collaborative prototyping and evaluation), and methods used in Organisational Ergonomics field (i.e. process mapping).

Summary of Research Phases

Overall, three phases of research, spanning six studies were undertaken. Hereafter these are referred to as studies 1, 2, 3, 4, 5, and 6. Collectively, these studies deliver on the

requirements for a valid methodology as outlined above. The first phase of research involves an analysis of the current task. This comprises an analysis of the overall Flight Crew task and the pre-flight, flight planning and briefing task. Following from the preceding analysis, several key socio-technical dimensions of task activity are analysed (i.e. process, context, teamwork, environment, tools and information). This research spans studies 1, 2, 3 and part of Study 4. In so doing, this phase of research delivers on the methodological requirement to specify the current task. This sets the stage for the specification of the future task and the related envisionment, prototyping and evaluation of the future tool concept, which forms the second phase of research. Critically, this phase of research is used to define the requirements for good briefing (i.e. good briefing practice), taking into account existing CRM theory, existing process design problems and potential process redesign requirements. This comprises three sequential stages of research spanning the second half of Study 4, Study 5 and the first part of Study 6. Thus, this phase of research delivers on the requirement to specify the future task in the context of an improved process. Further, it delivers on the requirement to advance a prototype of the emerging HCI tool concept – thus bridging the gap between requirements and design. The third phase of research focuses on determining the underlying operational and organisational processes necessary to the implementation of the new electronic Flight Plan at a particular airline, and the assessment of potential implementation barriers. This research was undertaken in Study 6. Thus, this phase of research delivers on the requirement to map the underlying process requirements necessary to the implementation of the HCI tool concept and the evaluation of implementation barriers.

Phase 1: Analysis of the Current Task

As part of the pre-flight, flight planning and briefing task, the crew brief on all aspects of the flight from start to end. Further, as outlined earlier, the pre-flight, flight planning and briefing task supports Flight Crew task activity more generally, in terms of the management of complexity and co-ordinating information inputs from different team members across different processes. In this way, to understand the pre flight, flight planning and briefing task, we need to understand the wider Flight Crew task. Therefore, the identification of new tool requirements necessitates the advancement of a task model on two levels. First, a model of the overall Flight Crew task in the context of the broader operational and organisational system is required. Secondly, a more detailed model of the pre-flight, flight planning and briefing task is required.

What is the scope of these two task models? In relation to the model of Flight Crew task activity taken generally, the Researcher is not endeavouring to analyse every aspect of Flight Crew task performance in detail. Overall, a high level picture of task performance in the context of the overall socio-technical system is required. Nonetheless, the relationship between Flight Crew task performance and certain key socio-technical elements must be

explored in more detail. As indicated in the analysis of this thesis problem, this includes process, team, tools and information and context. Further, issues related to ecological validity must be addressed. That is, the data collection methods must facilitate the capture of information about actual task activity, including informal task workarounds.

Following from this, a more detailed model of Flight Crew performance of the pre-flight, flight planning and briefing task is required. Firstly, the model must provide an explanation of the relationship between this task and the wider Flight Crew task. Further, it must provide an account of the relationship between task and process, team task performance requirements, Flight Crew use of procedures, the role of expertise, the role of context, the role of tools and information and environmental constraints. Critically, the pre-flight planning and briefing task is modelled at a level of detail, such that the initial HCI requirements can be established.

The preceding analysis suggests that no one method is sufficient for this purpose. Rather, an integration of methods is required. Overall, the task analysis approach reflects an integration of process mapping approaches (i.e. addressing process and task relationships) and normative HCI approaches (i.e. focus on the analysis of the current task).

Study 1 examines the socio-technical nature of Flight Crew task performance. In particular, the shaping influence of the process design on task activity is analysed. Overall, this analysis has a Flight Crew focus. In terms of scope, this includes all processes that impinge on Flight Crew task activity. Nonetheless, the particular analysis framework mostly focuses on the relationship between the design of the Active Flight Operations processes and Flight Crew task activity. Process mapping methods are used to elucidate team task activities at various points in the Active Flight Operations process, and how these impact on Flight Crew task performance. Further, Flight Crew use of tools and information and the impact of context on task activity is addressed - albeit at a high level. Moreover, the data collection framework facilitates the capture of information about Flight Crew use of procedures and in particular, informal task practices. In relation to Flight Crew performance of the pre-flight, flight planning and briefing task, similar task dimensions are explored.

Study 2 follows up on certain issues raised in the first study concerning dependencies between the Flight Planning process and the Active Operations Process. As such, this study elucidates the perspective of Flight Planning personnel on the process and task relationships identified in Study 1.

Study 3 investigates issues raised in Study 1 concerning the relationship between the Flight Crew task and the broader Safety/Quality/Improvement process. In so doing, this study elicits the perspective of Safety/Procedures Design/Training personnel on these process and task relationships.

In Study 4 user interviews and observations are used to validate the findings of Study 1 concerning the relationship between task and process, teamwork and the role of context.

Further, certain other socio-technical dimensions of Flight Crew task performance are investigated in more detail. User observations are conducted to elucidate actual task practices and environmental constraints (Vicente, 1999). Following from the distributed cognition framework (Hutchins, 1995a, 1995b, Hutchins & Klausen, 1996), research investigates how tools and information shape Flight Crew task performance. Specifically, the analysis of information flow considers information derived from the environment, from tools, from paper information resources and from team agents. Further, in line with Clark's research (1996), both the information and the nature of the information communication process are examined. In addition, the data collection approach elicits feedback about tacit knowledge and informal task practices. Study 4 also follows up on the findings of Study 1 in relation to Flight Crew performance of the pre-flight, flight planning and briefing task. Further, more detailed information is captured about this task. This includes task objectives and requirements, the impact of process on task activity, teamwork, CRM/TEM dimensions and processes, the use of procedures, and the use of tools and information resources. Task problems and Flight Crew recommendations in relation to resolving these task problems are also explored.

Phase 2: Specification of New Task Practice & Allied Tool Requirements

As noted previously, new tool requirements cannot be predicated on existing task models alone. We must also consider how the future task might be performed taking into account the task transforming power of new electronic tools. In this way, a future task model is required. This is undertaken in the second phase of research. Critically, the specification of the future task is embedded in activities related to the envisionment, prototyping and evaluation of the new tool concept. In this way, this second phase of research is heavily influenced by participatory frameworks and methods.

The first stage of research focuses on the envisionment of new tool requirements. User interviews conducted as part of the second phase of research in Study 4 are used to elicit feedback about Flight Crew problems with existing tools, and the requirements for improved tools. Further, prototyping methods are employed to obtain ideas pertaining to the future tool solution.

In the second stage, future tool requirements are analysed. Critically, the requirements for improved briefing tools are considered in the context of the emerging task models and broader Flight Operations information flow improvements. This includes information sharing improvements in relation to (1) operational processes (i.e. Active Flight Operation and Flight Planning Process) and (2) organisational processes (i.e. Safety/Quality/Improvement processes).

An initial prototype is then produced. This prototype is used as a basis for collaborative prototyping and evaluation. This follows from Bannon's (1991) argument that to evaluate future task practice and associated tool concepts, it is necessary for users to interact with a prototype of the future solution. This research comprises the first part of Study 5.

In line with participatory approaches, collaborative prototyping and evaluation sessions are used to further specify and evaluate the future tool concept. This spans the collaborative prototyping and evaluation activities in Study 5 and in the first part of Study 6. The particular HCI design and prototyping approach adopted is influenced by two approaches. Firstly, it borrows from Carroll's scenario based design approach (1995; 1997; 2000). Secondly, it draws upon the collaborative prototyping and technology envisionment techniques used by Bodker et al., (1985) and Muller (1993; 2003).

Phase 3: Specification of Underlying Processes and Implementation Barriers

As noted previously, it is also necessary to specify the underlying processes necessary to the implementation of the proposed tool concept. Further, implementation barriers must be addressed. The HCI literature does not provide guidance here. Therefore, participatory approaches are adopted for this purpose. This research spans the process specification activities conducted in Study 5 and Study 6, and the implementation workshop conducted in Study 6.

6. INTRODUCTION TO HILAS PROJECT

Introduction to Project

The Human Integration into the Lifecycle of Aviation Systems (HILAS) project is part of the Sixth Framework Programme for Aeronautics and Space Research, sponsored by the European Commission. The objective of this project is to develop a model of good practice for the integration of human factors research across the life-cycle of aviation systems. The project contains four parallel strands of work: the integration and management of human factors knowledge; the flight operations environment and performance; the evaluation of new flight deck technologies, and the monitoring and assessment of maintenance operations (HILAS Consortium, 2005).

The Flight Operations strand comprises seven European airlines, human factors researchers and technology partners. The critical objective of this strand is to develop and implement new processes and tools for monitoring and evaluating overall system performance, to support performance management, safety management, operational risk management,

process improvement and information sharing. Within the HILAS Flight Operations Strand, these new processes are referred to as Tool D. The proposed new technology tools are referred to as Tools A, B and C. The objective of Tool A is to support data collection (i.e. reporting) and to provide task support and safety feedback to Flight Crew. Tool B assists data integration, while Tool C supports data analysis and the communication of operational/safety feedback to relevant personnel.

Researcher Role

In terms of the HILAS work programme, the Researcher led the human factors research for the HILAS Flight Operations strand and acted as 'Work Package Leader'. The Researcher had overall responsibility for the design of the human factors methodologies and led reporting activities in relation to work package deliverables. Primarily, the Researcher focussed on advancing a model of Flight Crew task performance, for the purpose of identifying the requirements for improved Flight Crew tools, embedded in the Flight Operations process and supporting airline performance management and safety management processes. This links to the specification of Tool A as outlined above. New Flight Crew tool requirements were grouped into three categories; namely (1) task support, (2) performance feedback and (3) reporting. The requirements for an electronic tool assisting Flight Crew performance of the pre-flight, flight planning and briefing task, was conceptualized as a task support function.

Much of the functionality advanced in relation to Tool A - and specifically, the new electronic flight plan - links to the wider process and tool specification undertaken by other parties working in the HILAS project. In particular, this relates to the definition of an improved safety management system, deploying both proactive and reactive risk logics. Critically, certain arguments proposed in this thesis, in relation to making use of safety analysis data in the operation, is supported by this wider research. However, this research is not directly reported in this thesis.

Overview of Studies

This thesis reports on a subset of the research which the Researcher conducted as part of the work requirements for the HILAS programme. Specifically, it focuses on the advancement of an intelligent briefing tool, supporting Flight Crew performance of the pre-flight, flight planning and briefing task. Certain of the studies were conducted in sequence, while others were conducted in parallel. For more information, please see Appendix 2. High level research was conducted with five airlines. Hereafter, these are referred to as Airlines 1, 2, 3, 4 and 5. However, more detailed research was conducted with Airlines 2 and 5. In the

case of all studies, participants were contacted in advance by the HILAS airline representative to explain the overall research objective and to agree the research schedule.

Study 1 involves a high level examination of the Flight Crew task, along with the specific pre-flight, flight planning and briefing task, in the context of the Active Flight Operations process. Other processes that impinge on Flight Crew task performance are also examined, albeit at a high level. This study also involves an examination of existing airline performance monitoring methods and tools. First the researcher reviewed relevant Flight Operations documents. Following this, five process mapping workshops were conducted with partner airlines. This research forms the bedrock for the other five studies. Critically, the themes advanced in this study relating to Flight Crew task performance (i.e. both in relation to the overall Flight Crew task and the pre-flight planning and briefing task), Flight Operations process design and associated information flow problems, specific information flow problems associated with the design of the existing airline performance/safety management process, and Flight Crew requirements for improved briefing tools, are further developed in the subsequent five studies. In this way, this Study is foundational to the development of the thesis themes and arguments.

Study 2 addresses the Flight Planning process. A high level map of the Flight Planning process is advanced. Further, the pre flight, flight planning and briefing task is both mapped and analysed in the context of this process. As part of this, interviews and observations were conducted with a total of sixteen participants spanning Aircraft Pairing and Rostering, Dispatch and Flight Operations Control functions.

Study 3 follows up on certain of the issues raised in Study 1, concerning the relationship between the Flight Crew task and the broader Safety/Quality/Improvement process. Specifically, it focuses on the broader SMS process, of which performance monitoring/management and CRM training activities form a part. Three related sub-studies were conducted. This includes: (1) a high level study of airline performance management methods and tools, conducted with airlines 2, 3, and 5, (2) follow up research conducted with Airline 2 in relation to the Alta scenario and the airline's LOSA evaluation, and (3) follow up research conducted with Airline 5 in relation to the airlines CRM training programme and certain new tools developed by the airline. In so doing, the researcher analysed relevant process descriptions, safety material, CRM training material, and safety reports. User interviews were conducted with twenty five participants spanning several airline functions including Safety, Risk, Training and Procedures Design. Further, the researcher observed a CRM session.

Study 4 entails a more detailed analysis of the Flight Crew task. This research was undertaken with Airline 2 and 5. Overall, this comprises two phases of research. In the first phase, the findings of Study 1 in relation to the shaping influence of the process on Flight

Crew task activity are validated. Also, a more detailed investigation of the pre-flight, flight planning and briefing task is undertaken. The Researcher undertook a walkthrough of the briefing task, observed two pre flight briefing sessions, conducted two interviews with Flight Crew participants and rode jump-seat on seven flights with two airlines – namely airlines 2 and 5. The second phase of task analysis involves a more detailed analysis of the pre flight, flight planning and briefing task. Further, it investigates the requirements for improved tools assisting this task. As part of this, the Researcher conducted six interviews with Flight Crew participants.

Study 5 involves the participatory modelling of new tool prototypes, for the purpose of specifying the requirements for new tools assisting Flight Crew performance of the pre flight, flight planning and briefing task. As part of this collaborative envisionment and prototyping sessions were conducted with fifteen Flight Crew participants from Airline 5.

Study 6 follows up on Study 5 - further examining the requirements for an Intelligent Flight Plan, for the current flight only. Overall, this involved two phases of research. First, two participatory sessions were conducted with one Pilot from Airline 5. The objective of these sessions was to further advance the intelligent flight plan concept, and to specify the underlying flight operations process requirements. In the second part of the study, an implementation workshop was conducted with ten participants from Airline 5, spanning Flight Crew, Flight Planning, Dispatch, IT and Safety. The objective of this workshop was to further review and evaluate the proposed HCI design concept and to map and evaluate the operational and organisational requirements necessary to the implementation of this tool, at the airline. In this way, this last study is not Flight Crew centric. Rather, it spans the perspective of various Flight Operations and IT personnel.

Ethics Approach

The six studies do not involve deception or withholding of information. The six studies do not involve either physical risk, psychological risk (i.e. upset, worry, stress, fatigue, feelings of being demeaned) or social risk (i.e. loss of status, privacy or reputation) for the participants. Although participants were not asked to reveal information of an emotionally sensitive nature, they were invited to reveal information that might be professionally sensitive (e.g. confidential information which has implications for employee/employer relations).

Participants are protected under the terms of the EU Sixth Framework confidentiality agreement. Further, participant confidentiality is assured by the following steps taken by the Researcher:

- Participant information obtained through research was de-identified

- Research participant's names were not and will not be disclosed to other participants or other researchers.

Study 1: Process Mapping of the Active Flight Operation & High Level Investigation of Existing Airline Performance Monitoring Processes and Tools

1. CHAPTER INTRODUCTION

This chapter reports on the findings of the first HILAS study; process mapping of the Active Flight Operations process. Process mapping workshops were conducted with five airlines from October 2005 to April 2006.

As noted in the introduction, given the relationship between the process and task, the specification and implementation of new Flight Operations processes provides the means to transform Flight Crew task activity. That is, by changing the process and specifically changing what information is communicated to Flight Crew in terms of the introduction of an improved Flight Plan, it is possible to transform the way the task is performed.

Process mapping activities focussed on mapping the Active Flight Operations process, and in particular, the shaping influence of this process on Flight Crew task activity. Further, process mapping activities examined the relationship between Flight Crew task activity and the two other Flight Operations processes - namely the Flight Planning process and the Safety/Quality/Improvement process. Thus, before reporting on these activities, we must first understand the nature of these three processes. Further, we must elucidate existing models of Flight Crew task performance (taken generally), along with specific models of the pre-flight, flight planning and briefing task.

The process workshops also addressed problems with the design of existing performance management processes and tools. Specifically, the workshops endeavoured to identify how these processes might be improved both generally, and in relation to the provision of reports/task support feedback to Flight Crew. Thus, an introduction to existing performance management processes and tools is also provided.

As stated in the introduction, the advancement of new tools/systems provides the opportunity to improve information sharing between Flight Crew and the various agents with whom they co-ordinate with. Further, it provides the mechanism to deliver additional information to Flight Crew. One such tool is an Electronic Flight Bag (EFB). This is also reviewed in the introduction.

2. INTRODUCTION

Introduction to Flight Operations

Introduction

The Flight Operations process is structured in terms of three related processes: the Flight Planning process, the Active Flight Operations process and the Safety/Quality/Improvement process. However, the design of these processes follows from the existing Flight Operations concept. Therefore, to understand the nature of the Flight Operations process, we must first examine the principle behind the existing Flight Operations concept

Flight Operations Concept

In commercial transport, crew fly pre-determined routes (or flight plans) using fixed airways based on ground based navigation beacon locations. A Flight Plan (and associated route) is filed in advance of the flight, and signed off by Air Traffic Control (ATC). From an air traffic management perspective, this ensures optimum airway usage and appropriate aircraft separation, taking into account all commercial operations during a specific time period. The Flight Plan or route is understood as a series of permissions to fly at certain altitudes for specific time periods. These permissions are not final. Air Traffic Control (ATC) can change the actual flight route during flight. The distribution of functions between ATC and Flight Crew follows from the existing Flight Operations concept. The Air Traffic Control (ATC) function was introduced to ensure safe separation between aircraft. ATC rules and processes were agreed at the Paris Air Convention in 1919 and these were implemented in 1922. Largely, Pilot and ATC communication protocols follow these conventions. The role of ATC is to prevent aircraft collision and optimise airway usage at any given point in time. Specifically, ATC have a managerial role in relation to flight routing and aircraft separation. The role of Flight Crew is to transport passengers from the departure location to the destination location, in accordance with the Flight Plan and ATC instructions. Flight Crew must follow the fixed routes as detailed in the Flight Plan.

Flight Operations Processes

Each airline is responsible for the design of the specific Flight Operations processes required to support the implementation of the existing operational concept. This includes activities related to the Flight Planning process, the Active Flight Operations process and the Safety/Quality/Improvement process.

Primarily the Flight Planning process concerns the progressive development and specification of the Flight Plan, following agreement with relevant ATM agencies. The Flight

Planning process is structured in terms of three phases, (1) commercial flight planning, (2) aircraft pairing and rostering and (3) dispatch. This is discussed in more detail in Study 2.

Existing descriptions of the Active Flight Operations process take a flight centric perspective. The Active Flight Operations process is divided into three sequential process stages: pre flight, flight execution and post flight. Each of these process stages is structured in terms of a series of flight phases defined by the Air Transport Association (ATA). Airline flight operations manuals provide an account of this process in relation to Flight Crew task workflows at set flight phases. Implicit in this, is a description of the task requirements of other operational agents which interface with Flight Crew at different flight phases. This includes: Dispatch, Cabin Crew, Maintenance, the Co-ordinator and the Fuel Agent.

The Safety/Quality/Improvement process runs in parallel to the two operational processes. This process spans various organisational functions such as safety, training and procedures design. This process is outlined in more detail in subsequent chapter sections. Further, this process is examined in more detail in Study 3.

Introduction to Flight Crew

As noted in introduction, to identify the requirements for new tool supporting the pre-flight, flight planning and briefing task, we must first start with a model of the current task. This includes a model of the overall Flight Crew task, along with a model of the specific pre-flight, flight planning and briefing task. The following section provides a general introduction to Flight Crew task performance. Flight Crew task models as outlined in airline flight operations manuals and the associated theoretical literature, are examined in the next section. The literature pertaining to the pre-flight, flight planning and briefing task is reviewed in subsequent sections.

In the current operational concept, Flight Crew task activities involve actioning the Flight Plan, taking into account any changes requested by ATC. According to Pilot technical manuals, the primary objective of commercial Flight Crew is to ensure that the aircraft travels safely from the departure location to the destination location (De Remer, D., and McLean, D., 1993). Secondary goals include flying the aircraft economically (i.e. fuel consumption), speedily (i.e. on schedule), and providing quality customer service to passengers.

Flight Crew are classified into one of two ranks (i.e. 'Captain' or 'First Officer'). The Captain is responsible for approving the aircraft airworthiness and is 'in command' during flight. The First Officer is subordinate to the Captain. Both Captain and First Officer are involved in flying/navigating the aircraft. During flight the term 'Pilot Flying' (PF) is used to denote the crew member responsible for aircraft guidance and control. The other Pilot, referred to as the 'Pilot Monitoring (PM)', is responsible for interacting with ATC/Tower and verbalizing

checklists. Typically, both Captain and First Officer will alternate PF and PM roles during successive flight legs, or during a long haul flight.

For the safe execution of the flight and the achievement of the operational goal, Flight Crew must pose and answer a number of navigation and situation assessment questions at different points in the flight. This necessitates gathering, integrating and analysing information distributed across a range of team agents and technical resources. As highlighted by Endsley, Flight Crew control decisions and actions are based on the information available to crew and their assessment of this information (1988, 1995a, 1995b, 1999a, 1999b, 2000).

The practice of a range of safety behaviours on the part of Flight Crew throughout the flight is essential to flight safety. The integration of all relevant flight information and subsequent assessment of the fight situation is premised on a number of safety management strategies, first encountered by Pilots in airline training sessions. This includes the application of general Crew Resource Management (CRM) principles and specific CRM practices such as briefing (Johnston, 1993, 1994) and Threat and Error Management (TEM) techniques (Helmreich, R.L., Klinect, J.R., and Wilhelm, J.A., 1999; Klinect, J.R., Wilhelm, J.A., & Helmreich, R.L., 1999). Critically, the crew perform two formal briefings at set points in the flight (e.g. pre flight and top of descent). The nature of the pre-flight, flight planning and briefing task, is reviewed in more detail in a later section. Further, briefings are performed as part of checklist execution. Aside from this, the crew engage in ongoing informal communications/briefings throughout the flight. The appropriate application of airline procedures at different points in the flight also ensures the safe achievement of the operation goal. Lastly, the completion of a range of mandatory reports (both operational and human factors), along with certain voluntary human factors reports at the end of each flight, provides the Safety Department with feedback regarding the safety status of the operation.

Flight Crew Task Models

Introduction

The theoretical frameworks analysed in the introduction chapter suggest certain requirements for a valid task model. It is argued that a valid model must provide an explanation of the shaping influence of certain socio-technical elements on Flight Crew task performance. This includes: process, teamwork, context, the use of tools/information and environmental constraints. Further, such a model must elucidate real world task activity (i.e. informal task activities and task workarounds), as opposed to simply reflecting SOP's.

Airline Flight Operations manuals and the theoretical literature concerning Flight Crew task activity present several accounts of Flight Crew task performance. Overall, there is a lack of

integration across these different accounts. Specifically, these accounts focus on different dimensions of Flight Crew task performance, at different levels. In this way, it is difficult to obtain an integrated picture of Flight Crew task activity. Also, there are problems with individual accounts. Firstly, flight operations manuals present a normative description of Flight Crew task performance. It is suggested that task performance mostly involves following set procedures at particular flight phases. These normative accounts have been challenged by Loukopoulos, Dismukes and Barshi (2003). Loukopoulos et al., (2003) argue that SOP's are misleading insofar as they give the impression that procedures are linear, that the pilots have full control over their execution, and that the procedures flow uninterruptedly. Helmreich, Klinect and Wilhelm (1999) point to the phenomenon of procedural drift, which they attribute to crew complacency. Losa (2007) provides an alterative account of procedural drift - pointing to the impact of process design and operational complexity on the crew's ability to follow procedures. Lastly, Johnston (2003) provides an account of Flight Crew activity in relation to expertise. Diverse accounts of Flight Crew functions are also outlined. Critically, these accounts fail to address certain fundamental aspects of the Flight Crew role in commercial operations. Several theoretical accounts of Flight Crew task performance have also been proposed. A number of authors focus on particular socio-technical aspects of Flight Crew task performance. Hutchins (1995a) provides a theoretical account of Flight Crew use of tools. However, explanations of the relationship between task and process are thin on the ground. Lastly, the non technical dimensions of Flight Crew task performance are also discussed. These accounts have a theoretical focus. Nonetheless, they are useful in terms of drawing attention to the underlying socio-cognitive nature of Flight Crew task performance, and potential human factors problems that can occur.

Procedural Models

Airline operations manuals provide a procedural account of Flight Crew task performance. This includes descriptions of standard operating procedures (SOPs), procedures for non normal situations, emergency procedures and Crew Resource Management (CRM) procedures. These accounts suggest a deterministic model of Flight Crew task performance. Pilot workflows are characterized in relation to the performance of fixed tasks by either the Captain/First Officer and/or the PF/PM in sequential order, at set flight phases as defined by the ATA. Implicit in this, is the ideas that Flight Crew task performance is a matter of applying procedures and that these procedures are appropriate to a given situation. Do these procedural accounts reflect actual operational performance? Further, can SOPs always be followed?

The deterministic workflow descriptions proposed in airline SOPs have been challenged by Loukopoulos, Dismukes and Barshi (2003). Loukopoulos et al., (2003) analysed flight operations manuals (FOM), and observed training at two major US passenger airlines. This

study found that Pilots are frequently interrupted, forcing them to interweave, suspend and defer components of tasks (Loukopoulos et al., 2003). Further, Pilots are sometimes unable to execute a procedural step at the point at which it occurs in the written procedures, either because the larger situation makes it inappropriate to execute that step at that moment, or because the information necessary for the execution of a task step is not yet available (Loukopoulos et al., 2003).

The literature concerning procedural drift (Helmreich, R.L., Klinect, J.R., & Wilhelm, J.A. 1999; Klinect, J.R., Murray, P., Merritt, A., & Helmreich, R., 2003) presents another perspective on Flight Crew use of procedures. Procedural drift refers to the tendency of Pilots to become complacent about procedures, and in certain cases to wilfully infringe procedures/rules. In explaining this, the authors distinguish between wilful non compliance and non wilful non compliance. Wilful non compliance denotes deliberate violations of SOP. Non wilful non compliance refers to situations where Pilots unintentionally fail to follow procedures. Losa (2007) provides an alternative angle on the issue of procedural drift. In addition to complacency, Losa (2007) argues that procedural drift often results from problems inherent in the design of the Flight Operations process. According to Losa (2007), the design of the process often makes it difficult for Pilots to follow procedures. In support of this, Losa (2007) cites weaknesses in airline processes related to the sharing of information across Flight Operations, Maintenance, Dispatch and Ground Handling. Losa (2007) also notes that given low voluntary reporting rates, Flight Operations management often fail to identify the weaknesses in existing process design and the impact that this has on Flight Crew task performance.

Other authors address the inherent complexity in certain operational situations which makes it difficult to follow procedures. As noted by Johnston (2003), sometimes situations are indeterminate and it is not possible to follow procedures. In such situations, Pilots are often required to apply expertise (Johnston, 2003). For Johnson (2003), expertise can be defined in relation to a number of high level operational skills which Pilots draw upon, in deciding on a course of action. This includes strategic management skills (i.e. recognition, prioritisation, anticipation, projection and planning) and implementation skills and repertoires (i.e. mental flight path control, rules of thumb, gates and triggers, event flow patterns, generic response patterns, situational concepts and time management), (Johnston, 2003). In similar terms, Klein (1993) argues that in identifying a suitable course of action, Flight Crew regularly draw upon their prior experience and expertise.

Following a similar line of argument, Bennett (2006) suggests that there is a paradox at the heart of flight operations. "While many routines are pre-defined, the Captain retains her/his decision-making authority and is at liberty to abandon an SOP if s/he considers it wise. Pilots are therefore required to know when not to follow procedures. In flight operations, conformity is contingent upon circumstance and pilot judgement".

Overall, the role of procedures is not settled in the literature. Collectively, these different accounts provide an insight into the complex role of procedures in operations. As evidenced in the diverse views presented, procedures are followed, not followed and/or optimised, for different reasons. Thus it is necessary to unpack the issue of procedures in more detail. In particular, it is necessary to investigate the contentions of Losa (2007), regarding the impact of process design on Flight Crew use of procedures.

Flight Crew Task Functions

In principle, the literature surrounding Flight Crew task functions provides a high level overview of the Flight Crew task. Several different models of Flight Crew task functions are outlined. In general, these follow from normative accounts of Flight Crew task functions, as outlined in airline flight operations manuals. Ricks, Jonsson and Rogers (1993) propose that the traditional model of Flight Crew functions (i.e. aviate, navigate and communicate) be reformulated to included systems management. Abbott (1993) and Abbott and Rogers (1993), have extended this definition to include task management. An alternative approach has been propounded by Theunnisen (1997). Flight Crew task performance is classified in term of three interconnected activities which allow crew to manage the navigation problem. This includes navigation, guidance and control. Arguably, these accounts reflect a narrow conception of the Flight Crew task. Firstly, these formulations fail to account for Flight Crew management of different levels of complexity. The team concept embedded in these definitions appears local in focus. That is, it does not reflect Flight Crew co-ordination with wider agents, involved in both similar and different processes. Also, Flight Crew safety behaviour (i.e. briefing, reporting, the application of SOP's and CRM behaviours) is not addressed.

Socio-technical Descriptions

Process

The shaping influence of the existing flight operations concept on Flight Crew task performance is not explicitly addressed in the literature. However, the literature highlights several problems facing Flight Crew arising from the design of the existing operational concept and specifically, the managerial role of Air Traffic Control (ATC). This includes issues related to congestion and difficulties contacting ATC. Currently, new operational concepts are being proposed to ameliorate these problems. These receive significant attention in the literature (European Commission, 2001, 2002; Group of personalities, 2001).

To date, the impact of flight operations process design on Flight Crew task performance has not been attended to. In addition, the relationship between Flight Crew task performance and the design of both Maintenance and Ground Operations processes has not been addressed. This requires further analysis.

Teamwork

Airline Flight Operations manuals provide a procedural account of Flight Crew teamwork. This spans different levels of teamwork including cockpit teamwork (i.e. between Flight Crew), Flight Crew interaction with the broader operational team, and Flight Crew interaction with ATC. Primarily, the focus of these accounts is on communication protocols, when information is shared, and how information is shared. The actual information shared receives less attention.

Airline operations manuals outline cockpit communication/co-ordination procedures at set flight phases, linking to specific airline CRM procedures. This comprises formal briefings, checklist briefings and the application of the sterile cockpit concept during the descent, approach and landing flight phases. Airline procedures also define Flight Crew communication requirements with a range of roles at set flight phases. This includes communication with Cabin Crew, Dispatch, Maintenance, the Fueller, the Boarding Agent and the Co-ordinator. However, Flight Crew interaction with Flight Operations Control is not accorded much attention. In relation to ATC, airline procedures define appropriate communication mechanisms and protocols for exchanging information, following from the current flight operations concept. Overall, SOPs suggest that Flight Crew communication (i.e. both internally and with other operational personnel and ATC) occurs at predefined times in the process. Does this reflect operational reality? Do the crew receive the right information at the right time from relevant roles? If not, how does this impact on Flight Crew task performance? Further, as proposed by McDonald (2005) and Sachs (1995), do informal communication/co-ordination processes occur?

Tools

As mentioned in the introduction, Hutchins (1995a, 1995b) provides a theoretical account of Flight Crew use of tools and information resources in relation to the Distributed Cognition Framework. The relationship between aircraft automation and Flight Crew task performance also receives much attention. Specifically, the automation literature provides an account of Flight Crew use of different cockpit systems, in relation to the 'aviate' and 'navigate' task functions, and associated information flow requirements. As pointed out by Wickens (1999), given automation advances over the last decade, Pilots share responsibility for different flight tasks with cockpit systems. Three levels of automation/intelligence have been defined. These are characterized by the degree of human involvement with the system (Sheridan, 1992; Wickens, 1999; Wickens, Mayor, Parasuraman and McGee, 1998). Although useful, this literature does not present a complete account of Flight Crew task activity. This literature presents a Flight Crew/flight centric perspective on certain cockpit interactions. Arguably, a more concrete explanation of Flight Crew interaction/information flow with other agents in support of these 'aviate' and 'navigate' tasks is also required. Further, the literature does not

provide an explanation of Flight Crew interaction with different tools and information resources while off duty. How does this impact on Flight Crew task activity while on duty? This requires further investigation.

Non Technical Performance Concepts

Several theoretical descriptions of the non technical dimensions of Flight Crew task performance have been advanced. For the purpose of this study, we will focus on a subset of these concepts – namely, situation awareness, situation assessment, task management and information management.

According to Endsley (1988, 1995a, 1995b, 1999a, 1999b, 2000), for the safe operation of the aircraft, Flight Crew must anticipate changes in flight conditions or future traffic patterns. That is, they must think ahead of the aircraft. This ability is termed 'situation awareness'. Endsley (1988, 1995a, 1995b) distinguishes the concept of situation awareness from process of situation assessment. In Endsley's view, situation assessment refers to the active process by which operators develop situation awareness. Situation awareness is the product of that process.

As highlighted by Endsley (1988, 1995a), Pilots use information to form an appropriate assessment of the situation. Critically, this information must be current and reliable so that Flight Crew can form an appropriate assessment of the situation. In addition, the relationship between situation assessment and risk assessment has been highlighted. Carol (1992) links the process of situation assessment to threat and error management processes. According to Carol (1992), situation assessment is the *"pilots (or aircrew's) continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast and then execute tasks, based on that perception"*.

Several authors emphasize the team nature of situation awareness (Salas, E., Prince, C., Baker, D., & Shreshta, L. 1995). In explaining this, Salas et al. (1995) propose that a team is made up of a distinguishable set of two or more people, each having specific interdependent functional roles with a limited lifespan. Further, Salas et al., (1995) argue that the internal cognition of an individual in the group can affect the external cognition of the team as a whole.

Existing information behaviour models provide an account of Flight Crew information management in relation to specific flight management tasks, as part of the Active Flight Operations process. A range of models of Flight Crew information behaviour have been proposed. This includes certain general information management accounts, such as those provided by Von Thaden (2004) and Wilson (1997), and accounts which focus on particular information processing stages (Dervin, 1983; Ellis, 1989; Wilson, 1981; Wilson, 1997). Certain deficiencies in these accounts can be identified. No attention is paid to other information management activities, such as reporting at the end of the flight. Further, off duty

information management activities are not alluded to. In addition, the literature does not provide an account of the communication process, underlying Flight Crew information sharing with other agents. Potentially, as stated by Losa (2007), the broader process design has an impact on the nature of these communication processes. However, an explanation of the relationship between Flight Crew information flow and the broader process design is not provided. Overall, this requires further research.

Theories of Flight Crew task management have also been outlined. According to Funk, in a dynamic system, the state of each task continuously changes. As a result, the relative urgency with which each task must be completed also changes. Thus Flight Crew must continuously perform the function of task management in order to maintain awareness of the changes in the state of the system and make the necessary revisions to the task prioritization. Funk defines cockpit task management (CTM) as the *"initiation, monitoring, prioritization, execution, and termination of multiple, concurrent tasks by Flight Crews"* (1991). Similarly, Loukopoulos et al. (2003) suggest that the specific cognitive demands of concurrent task management include interweaving tasks, monitoring tasks, suspending tasks and deferring tasks. Overall, the above accounts provide a crew-centric explanation of Flight Crew task management. In this sense, they focus on one aspect of Flight Crew task management (i.e. monitoring of cockpit tasks). An account of the crew's broader monitoring of those tasks performed by other team agents which directly or indirectly links to their own tasks is not provided.

Pre Flight Planning and Briefing Task

The pre flight planning and briefing task is performed at the start of every flight. Depending on the crew situation, it is either performed in the crew/dispatch room after the crew check in for the first flight of the day or in the cockpit during the aircraft turnaround.

Airline flight operations manuals provide a normative description of this task. Primarily, these manuals describe the operational aspects of this task. This includes the review of flight routing and weather information and the assessment and signoff of fuel requirements (De Remer, D., and McLean, D., 1993). Overall, these task descriptions are quite high level. Crucially, these descriptions do not provide an account of the structure of the briefing, the role of different team members and their specific information requirements. Moreover, limited practical guidance is provided. For example, flight operations manuals do not detail what the minimal requirements for a good briefing are, when and how a re-brief should be undertaken, and what core aspects of the briefing the crew should focus on, if there is limited time to perform the briefing, and/or if a re-brief is required.

Bennett's (2006) longitudinal ethnographic study of the *'lived experience'* of aircrew flying operations at a low cost airline makes some interesting points in relation to Flight Crew task

activities at the pre-flight, flight planning and briefing stage. In Bennett's analysis, this task spans two overall task phases. These are referred to as the 'report' and 'planning' phases. In relation to reports phase, Bennett notes the following: *"Crew rooms could be busy and noisy with incoming crews filing end-of duty reports and the Base Administrator and Base Captain dealing with queries. Outgoing crews had to plan their duty in the midst of this activity"*. Further, he goes on to state that on one occasion, *"there was not a Flight Plan available for the Captain"*.

In relation to planning, Bennett (2006) observes that the flight planning task primarily concerns the review of the flight plan, and specifically weather and fuel uptake. According to Bennett (2006), *"Although exchanges were polite and convivial with authority positions underplayed, the meetings had identifiable convenors leaders (the Captain and SCCM, respectively)"*. Interestingly, Bennett (2006) does not refer to Flight Crew application of TEM behaviours or any explicit team building protocols, at this stage. Rather, these are referred to at a later stage in relation to the joint briefing between the Flight Crew team and the Cabin Crew team.

The Crew Resource Management (CRM) literature illuminates the human factors background to the briefing task. Specifically, it confers sense on the role of briefing in terms of fostering teamwork and supporting the development of a common situation picture (Cooper, White and Lauber, 1980). In so doing, the CRM literature provides a framework in which to conceptualize the requirements for a good briefing (i.e. teamwork and situation assessment). As defined, a good briefing involves the joint review of information, joint situation assessment and joint decision making in relation to flight decisions. By implication, the practice of such techniques will have a positive impact on the briefing task. However, the CRM literature does not explicitly state how these techniques are practically applied as part of the pre-flight, flight planning and briefing task.

The TEM literature also alludes to briefing (Helmreich, Klinect & Wilhelm, 2001; Helmreich & Musson, 2000; Klinect, Wilhelm & Helmreich, 1999). As defined, the joint review and management of flight threats at different points in the process is essential to flight safety. Nonetheless, the TEM literature does not provide concrete guidance as to how TEM strategies might be incorporated in the pre-flight, flight planning and briefing task? What does this involve? How should flight threats be categorised? At what point in the briefing process should this be addressed?

The human factors literature reports on more general crew problems arising from the introduction of low cost operations. In the new lost cost environment, crew often fly many short range flights in one day. Further, turnaround times have been reduced. Stewart (2006) and Stewart and Abboud (2005a; 2005b) highlight the impact of new crew rostering practices on the fatigue levels of Flight Crew. As pointed out by Bennett (2006), these new rostering

practices also have an impact on team building. Typically, crews are not rostered together for multiple sectors. The cockpit team often changes over the course of a working day. As such, crew may be meeting for the first time and it may be difficult to form a team (Bennett, 2006). The impact of low cost business models on crew performance of the pre-flight, flight planning and briefing task has not been explicitly analysed. Do shorter turnaround times impact on the time available for the pre flight, flight planning and briefing task? In addition, more general problems related to Flight Crew execution of this task are not discussed.

Much information is available about the tools used by Flight Crew as part of the pre-flight, flight planning and briefing task. This is referred to as the Flight Plan and/or the Briefing Package. Depending on the airline process and technical resources, the Flight Plan is provided in paper format (i.e. over a series of printed pages) or it is accessible electronically in the crew/dispatch office, using a desktop computer, and printed out by crew. Typically, the Dispatcher provides the crew with flight plan information for all sectors at the beginning of their day/duty, in the crew/dispatch room. Flight plan updates are then communicated to the crew directly using ACARS, or indirectly via the Co-ordinator (i.e. a paper version of the flight plan), later in the day.

The Flight Plan is used throughout the flight, but most especially during the flight planning and briefing sessions undertaken at the pre-flight, and top of descent flight phases. In principle, the Flight Plan sets the scene for the flight, providing the crew with all the necessary information to perform the flight. Key information imparted includes: the flight number, the aircraft registration, the flight status (in air or landed), the aircraft technical status and location (e.g. gate), routing information, weather information (including different weather charts), fuel figures, alternates, crew details, passenger information, Notices to Airmen (NOTAMS) and load information.

Pilots use this information to form an overall picture of the flight and to anticipate any problems that may occur. The literature does not explain how the Flight Plan is used by crew in terms of setting the scene for the flight, ordering fuel and signing off the Flight Plan. In this sense, several questions are left unanswered. What information is most important? What is the running order for this information review? Does the existing Flight Plan provide crew with all necessary information? Are there an information gaps? If so, how does this impact on task execution? What workarounds are undertaken by Pilots to mitigate potential negative outcomes?

All relevant parties have access to flight plan information (i.e. Flight Crew, Dispatch, Co-ordinator, Flight Operations Duty Manager and ATC). As such, the Flight Plan becomes the main reference point for all negotiations concerning flight changes. However, airline flight operations manuals do not explicitly describe this process. How does the work of these other roles impact on Flight Crew execution of the pre-flight, flight planning and briefing task?

The existing Flight Plan is not integrated with airline Safety Management Systems (SMS). As such, the current Flight Plan does not relay flight specific threats information to the crew. This information is in the system but it is not being exploited to its full potential. Is this a problem? Would this feedback enhance flight safety?

In addition to the Flight Plan, the crew review different charts/maps detailing navigation procedures. This includes: Standard Instrument Departure Procedures (SID), Standard Terminal Arrival Routes (STAR), Instrument Approach Procedures (IAP) and airport charts. These charts/maps are mostly provided in paper format. As reported by Chandra, Yeh, Riley and Mangold (2003), the paper format of these tools has led to many problems. This includes difficulties accessing information and lack of context specific information. For this reason, Electronic Flight Bag's (EFBs) have been introduced to improve crew access to existing paper resources. However, in the commercial field, specific EFB functionality has not been advanced in relation to the Flight Plan.

Despite the plethora of new technologies being introduced to commercial cockpits, cockpit designers have not focussed on making improvements to the existing Flight Plan. Is this an issue for the airlines? What, if anything are the airlines doing in relation to addressing these problems? This requires further investigation.

Introduction to Performance Management and Safety Management Systems

Introduction to Flight Safety

Flight safety is not confined to Flight Crew behaviours in the cockpit. Flight safety is also supported by a range of airline performance management/safety management activities on the ground, linking to the airline's safety/quality/improvement process, and specifically to the day to day functioning of an airline's safety management system (SMS). Critically, an airline must identify their location in the safety space, to ensure that they stay within the defined safety/risk boundaries (ICAO, 2009). Central to this, is the monitoring and evaluation of performance. This in turn links to diverse processes such as risk assessment, quality management, procedures design and training (ICAO, 2006; 2009).

Performance Monitoring/Management

Airlines use a range of tools/methods to gather information about the safety status of the operation. Traditionally these tools are grouped into two types: those that focus on gathering human performance information using either self report (i.e. Air Safety Reports, Mandatory Occurrence Reports, Confidential Reports and Anonymous Reports), or observer based methodologies (i.e. Non Technical Skills Evaluation, Line Checks, Line Operations Safety

Audit and Line Operations Flight Training), and those that focus on gathering aircraft performance information (i.e. Flight Operations Quality Assurance). Feedback from these tools is used to action any short term safety/risk management actions, along with more strategic improvements (i.e. process/procedures re-design, enhanced training and so forth).

LOSA evaluations have been undertaken by many airlines. The purpose of a LOSA evaluation is to identify threats to safety, minimise the risks that such threats may generate, and implement measures to manage human error in operational contexts (FAA, 2005). During a LOSA evaluation, trained observers observe real-life operations providing feedback about Flight Crew threat and error management skills. Evaluations are conducted under strict non-jeopardy conditions.

Crucially, these tools fail to provide a real-time picture of routine operations supporting predictive risk management (Cahill, McDonald, Ulfvengren, Young, Ramos and Losa, 2007; Cahill and Losa, 2008). Further, the use of many discrete tools presents additional information management challenges. Much valuable data is gathered about the operation. Yet this data is gathered, analyzed and stored in different formats, making it difficult to obtain an overall integrated safety/risk picture (Cahill et al, 2007; Cahill and Losa, 2008). Further, considerable information is available about existing performance monitoring processes/methods and tools. However, little information is offered about the specific airline processes for analysing this data, identifying change actions, and communicating feedback to relevant operational and organisational functions. Moreover, technology support for these functions appears poor.

Airlines are currently introducing (or are in the process of introducing) enhanced performance management tools, in accordance with regulatory guidance (ICAO, 2006, 2009). Critical to these improved approaches is the provision of feedback to relevant personnel. Currently, safety analysis feedback is provided to relevant organisational functions such as Training and Procedures design. The nature of these information sharing processes is defined in airline SOPs. In principle, feedback is provided to relevant operational personnel (i.e. Flight Planning, Dispatch and Flight Operations Control). However, these processes are not always optimized to ensure that all relevant roles have access to the right information, or share information to facilitate the processes outlined above. As a result, Flight Planning and Flight Operations management personnel often engage in informal information gathering and sharing processes to enhance operational efficiency and flight safety, and circumvent problems in the existing process design. This requires redress. Further, is the outcome of these safety/risk assessments communicated to Flight Crew in a suitable manner? Typically, the crew receive feedback concerning the safety levels of the fleet and associated airline safety case studies, via safety bulletins published by the airlines safety department. However, this information is not currently communicated to Flight Crew, in the form of a flight specific risk/safety instruction. Is there a safety implication

to this? Arguably, the relationship between existing airline performance monitoring//management processes and the provision of task support to Flight Crew, at the pre-flight, flight planning and briefing stage, has not been adequately addressed.

Safety Management System

Airline performance management processes and tools, form part of the airline's overall safety management system (SMS). The International Civil Aviation Organisation (ICAO) defines a safety management system as *"an organized approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures"* (2006). Further, ICAO define a safety program in relation to *"the regulations and directives for the conduct of safe operations in aviation from the perspective of aircraft operators and those providing air traffic services, aerodromes and aircraft maintenance" (2006)*. All such parties are required to develop a safety programme in accordance with ICAO criteria. The purpose of a safety management system is to provide a systematic way of controlling risk and to provide assurance that the risk controls adopted are effective.

Crew Resource Management

Introduction to Crew Resource Management

Crew Resource Management (CRM) is a training framework which applies human factors knowledge to an understanding of crew interaction. CRM is defined as the effective utilisation of all available resources (i.e. crew members, aeroplane systems and supporting facilities) to achieve a safe and efficient operation. According to proponents of CRM theory, errors arise from poor teamwork, poor communication and inadequate situation assessment (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b).

Underpinning CRM frameworks are several assumptions concerning teams and the benefits of team-building and teamwork. First, CRM theory starts with the precept that teams are not automatically effective (Burke, Wilson and Salas, 2003). Rather, teamwork needs to be fostered. Further, as pointed out by Green, Muir, James, Gradwell and Green (1996), it is assumed that *"a decision made by a group will be better in quality than the average decisions made by the members of the group"*. Moreover, it is assumed that *"team communication, cohesion, and coordination are all correlated with team effectiveness"* (Brannick, Roach & Salas, 1993). In this way, as stated by Burke et al., (2003): *"CRM represents a human factors intervention which attempts to mitigate the effects of stress on performance through the promotion of teamwork"*.

To this end, CRM theory points to the importance of teamwork and in particular to the value of crew briefings. It is argued that the execution of team briefings at different points in the

flight helps foster teamwork, thereby mitigating problems relating the development of a common situation picture and joint decision making.

Threat & Error Management

Threat and Error Management (TEM) is a sub-set of CRM behaviour, focussing on crew management of threats and error mitigation and management strategies (Helmreich, Klinect & Wilhelm, 2001; Helmreich & Musson, 2000; Klinect, Wilhelm & Helmreich, 1999). The TEM model provides an explanation of Flight Crew task performance, in relation to crew management of different kinds of threats, to avoid errors and/or unacceptable aircraft states. Underlying the TEM model is a distinction between latent threats, overt threats, human error, error management and error outcomes (Helmreich, Klinect & Wilhelm, 2001; Helmreich & Musson, 2000; Klinect, Wilhelm & Helmreich, 1999).

Following from Reason (1990), Helmreich et al. (2000, 2001) distinguish latent threats (i.e. threats that exist in the organisation) and overt threats (i.e. threats present on the day). It is argued that risk comes from both expected and unexpected threats. Expected threats include factors such as terrain, predicted weather, and airport conditions. Unexpected threats include ATC commands, system malfunctions and operational pressures. Risk can also be increased by errors made outside the cockpit (i.e. ATC, Maintenance and Dispatch). Collectively, these three sets of threats/risks are referred to as external threats. These are contrasted with threats/risks that arise within the cockpit (i.e. crew based errors).

According to Helmreich (1996b), external threats are countered by the defences provided by Crew CRM behaviours. When successful, these lead to a safe flight. However, the response by the crew to recognised external threat or error might be an error, leading to a cycle of error detection and response. In addition, crews themselves may err without any external factors. Again CRM behaviours function as the last line of defence. If the defences are successful, error is managed and there is recovery to a safe flight. However, if the defences fail, this may result in a further error, a safety critical event/incident, and/or an accident.

In support of this, Helmreich et al (2000, 2001), propose a related model of Flight Crew error management. As part of this, Helmreich et al (2000, 2001) distinguish error types, error responses or countermeasures, error outcomes or consequences, and undesired aircraft states. Crew errors are classified into five types; intentional non compliance, procedural, communication, proficiency and operational decision. Further, three types of error response are differentiated - namely trap (i.e. the error is detected and managed before it becomes consequential), exacerbate (i.e. the error is detected but the crew action makes the situation worse or leads to a poor outcome) and fail to respond (i.e. the crew fail to detect the error, or ignore the error). In addition, three types of error outcomes are defined. This includes inconsequential, aircraft state and additional error. Undesired states can be mitigated, exacerbated or there can be a failure to respond. Further, it is argued that there are three

possible resolutions of the undesired aircraft state. This includes recovery (i.e. the risk is eliminated), additional error (i.e. the action introduces a new cycle of error), or a crew based incident or accident (Helmreich et al, 2000, 2001)

Several problems with the TEM framework have been identified. Firstly, the TEM framework separates technical and non technical performance. Moreover, the link between a technical procedure, a TEM/CRM procedure/behaviour and an aircraft state is ambiguous. Arguably, performance involves the enactment of both technical and non-technical skills which result in changes in aircraft states (the results of which either stabilize or destabilize the operational process). These skills/actions and the consequences of these actions cannot be separated. Moreover, the TEM model does not provide an explanation as to how individual errors along with different error types relate across the overall flight operations process timeline. A safety critical event might emerge following a chain of events, spanning a number of related errors and/or error types. Further, the TEM model does not provide a detailed account of the relationship between external threats and Flight Crew task performance. Potentially, this follows from an analysis of the broader operational and organisational context for Flight Crew task performance, and in particular, an assessment of process and task dependencies. Also, this model does not provide an account of TEM activities from a Pilots perspective. This includes a description of the TEM process, how Pilots rank potential threats, and how Pilots brief on threats. More generally, the TEM literature does not provide an account of crew TEM activities at the pre-flight, flight planning and briefing stage.

Electronic Flight Bags (EFBs)

Supplemental flight information (traditionally presented in paper format and carried in the pilot's flight bag) is now being presented in digital format. This digital medium is termed the Electronic Flight Bag (EFB), (Shamo, 2000). Existing EFB hardware includes portable digital assistants, tablets and laptop systems.

Primarily, EFB's' are used by commercial transport Pilots for the performance of flight management tasks, during flight and in the aircraft turnaround. Currently, the range of functionality supported includes flight planning, aircraft performance calculations (e.g. weight and balance calculations, takeoff calculations and landing calculations), weather and situation displays, flight log reporting, aircraft defect reporting, communications and document viewing (checklists, aeronautical charts and maintenance manuals). More advanced EFB functionality includes pathway displays and taxiway guidance systems, using synthetic vision capability (Chandra, D., Yeh, M., Riley, V., & Mangold, S.J. 2003).

The Federal Aviation Administration (FAA) classifies EFB equipment from a self-contained independent (portable) system to a system with multiple data link capabilities that interface with aircraft systems (2003). In cooperation with the FAA, the Joint Aviation Authority (JAA)

has provided temporary guidance information regarding EFB certification, airworthiness and operational use (2004). There is much similarity between the FAA directives and current JAA proposals. In both cases, Class 1 EFB's are fully portable and not connected to aircraft systems. The JAA specifically refers to these systems as controlled Portable Electronic Devices (PEDs). Class 2 EFB's are portable but connected to the aircraft during normal operations. Such devices can receive data from aircraft avionics systems, but cannot send data to these systems. The FAA requires an administrative control process for the approval of Class 2 devices; the JAA considers Class 2 devices to be controlled PEDs and requires airworthiness approval. Class 3 EFB's are fully installed/integrated systems and are not portable. Both the FAA and JAA require airworthiness certification covering both hardware installation and qualification.

As highlighted by Chandra et al (2003), this new EFB format provides opportunities to exploit information presentation functions not possible with paper (e.g. de-cluttering information, presenting timely information and pre-populating information). Further, it facilitates improvements in information access. Chandra does not provide detailed information about how EFB's are used from an operational perspective (i.e. what information is presented on the EFB, how do EFB's supports group work with other operational agents and do one or both crew members have an EFB). Specifically, the use of EFB's in terms of solving both process and task problems related to Flight Crew information sharing with different operational agents, requires further elucidation.

3. RESEARCH DESIGN

Objectives

The high level objectives of the process workshops included:

- To understand the shaping influence of the Active Flight Operations Process on Flight Crew task performance
- To map the Active Flight Operations Process, including team performance requirements at different ATA flight phases and/or process gates and associated process outputs
- To identify process facilitators and blockers and to explore the human factors dimensions of these
- To understand the impact of other processes (i.e. other Flight Operations processes, Maintenance Processes and Ground Handling processes) on Flight Crew task performance

- To understand the pre-flight, flight planning and briefing task in the context of the broader Flight Operations Process
- To elicit information about airline performance monitoring approaches and tools
- To identify solutions/recommendations (both short and long term) to any problems identified (i.e. both in relation to process design and existing performance monitoring tools).

Method

Five process workshops were conducted in conjunction with researchers from other partner universities and business consultants from a Small to Medium Enterprise company (SME), located in Ireland. The specific methodological approach was devised between the Researcher and the SME partner. This involved an integration of a business process mapping approach with a human factors/social process analysis approach. Researchers from other partner universities acted as observers in the workshops.

Prior to attending each workshop, information pertaining to existing Flight Operations processes, and specifically, Flight Crew standard operating procedures (SOPs) was reviewed. In addition, documentation concerning airline performance monitoring activities was reviewed. Following this, a checklist of issues to be discussed at the workshop was prepared.

The structure of each workshop was as follows. First the overall process was mapped. In relation to the first two workshops (i.e. workshops 1 and 2), this was led by the SME. However in the subsequent workshops (i.e. workshops 3, 4, and 5), this was led by the Researcher. Following this, the Researcher led a discussion of human factors issues. First, the different human factors problems that participants highlighted through the course of the process mapping activities were reviewed. Existing performance monitoring approaches were then reviewed. As part of this, the Researcher referred to relevant notes prepared in advance of the workshop. An overall problem solving session focussing on both the human factors issues identified, and existing airline performance monitoring methods and tools, was then undertaken. Participants were invited to record issues/problems on a series of post it notes. These were posted on the wall. These problems were then grouped and organised into a series of themes by the group as a whole. The group then discussed how these problems might be resolved, both in the short and longer term.

The Active Flight Operations process includes three sub processes (1) pre-flight, (2) flight execution and (3) post-flight. Process mapping activities focussed on a subset of flight phases/process gates, associated with these sub processes. In relation to pre flight, two process phases were explored (1) flight planning and dispatch and (2) aircraft release and

turnaround. In relation to flight execution, only the approach and landing phase was explored. Other process phases such as takeoff, climb, and cruise were not investigated. The post flight phase (i.e. reporting) was not mapped. The two other flight operations processes - the Flight Planning process and the Safety/Quality/Improvement process were not examined. Further, the overall Maintenance process, which links to the Flight Operations process, was not reviewed. Nonetheless, certain aspects of the Maintenance process were examined in relation to the aircraft turnaround and release process. Further, process mapping focussed mostly on the Flight Crew role. Flight Crew were treated as the overall co-ordinating interface for the flight operation. In this respect, the task requirements of other roles (i.e. Cabin Crew, Co-ordinator, Maintenance, Flight Operations Control and ATC) were mapped in relation to the achievement of the overall process and specifically, Flight Crew task requirements.

The specific process mapping methodology evolved through the course of the workshops. The first two workshops focussed on mapping the high level process and associated task steps of Flight Crew and other operational actors, in accordance with the specification of flight phases as defined by the Air Transport Association (ATA). As part of this, the SME documented the emerging process model in Web Sphere. During the course of Workshop 3, an alternative structuring logic for mapping the Active Flight Operations process was advanced. In this new logic, the process was structured in terms of a series of process gates as opposed to flight phases. Specific process gates were listed on a whiteboard, against the backdrop of a visualization of the flight profile. These were reviewed and discussed until an overall consensus was agreed. Following this, participants were asked to list the tasks required by each operational role to move from one process gate to the next, and to highlight any prior and parallel dependencies. Participants were also invited to provide information in relation to tools and information resources used and environmental constraints. The participants were then invited to detail the overall outcome of these task activities, in terms of a series of states. This included process states, aircraft states, Flight Crew states, broader operational team states, tool states and information states. Lastly, participants were invited to comment on task blockers and facilitators.

During the course of Workshop 3, participants reached agreement as to specific airline process gates, team task performance requirements and associated states. These were reviewed and modified in subsequent workshops (i.e. workshops 4 and 5). In the case of workshops 4 and 5, a generic process map detailing process gates, task requirements and outcomes/states was presented to participants. Participants were then invited to validate the process map – editing relevant process phases and gates to better reflect their airline's process.

In relation to workshops 1 and 2, the SME/technology partner documented the emerging process maps using Web Sphere. Process maps for workshops 3, 4 and 5, were

documented in by the Researcher, using Microsoft Word. Also, human factors issues and improvement suggestions for all workshops were recorded in Microsoft Word document. A summary of the Researchers' observations for each process workshop is available on the CD accompanying this thesis.

Following each workshop, a report was produced which detailed human factors issues and improvement suggestions. Further, the collective workshop findings were analysed. As part of this, the following process maps were advanced:

- High Level Process Map 1: process phases, process sub-phases and flight phases (all airlines)
- High Level Process Map 2: process phases, process sub-phases, process gates and process states (3 airlines)

The first of these process maps is presented in the results section in Table 4. The second of these process maps is presented in the results section over a sequence of tables – Table 6, Table 7 and Table 8.

In addition, the team task performance picture and underlying process framework for each process gate were analysed. A series of templates for each process gate was developed. The specific templates were populated with a synthesis of data from all five workshops. For an example of this template, please see Table 1 below. This analysis (i.e. analysis of team task performance requirements at each process gate) is presented on the CD accompanying this thesis.

Table 1: Process Gates & Team Task Performance Picture (Study 1)

Process gate												
Prior Dependencies												
Collective Tasks Required By Operational Team to Achieve Critical Point/State	Flight Crew				Cabin Crew		Dispatcher	Flight Operations Control	Co-ordinator	Maintenance	Ground Handling	ATC
	CPT	FO	PF	PNF	Senior	CC						
Task Environment												
Task Tools & Information Resources												
Collective Task Output/Result After State	Process											
	Flight Plan											
	Aircraft											
	People											

	Tools	
	Environment	
Process Blockers / Key Issues related to achievement of different states		
Process facilitators (Workarounds , Improvisations & Good Points)		
Later Dependencies		

Flight Crew task performance in relation to each process gate was also analysed in more detail. In so doing, a second series of templates reflecting a synthesis of process workshop findings for each process gate was advanced. Specifically, this presented a breakdown of Flight Crew tasks (i.e. role/task matrix) for each process gate. For an example of this template, please see Table 2 below. The actual role task matrices produced for each process gate are available on the CD accompanying this thesis.

Table 2: Process Gates & Flight Crew Role/Task Matrix (Study 1)

PROCESS GATE INFORMATION / CRITICAL POINT INFORMATION					
PROCESS PHASE					
PROCESS SUB-PHASE					
CRITICAL POINT					
FLIGHT CREW: ROLE/TASK MATRIX					
No	Task	PF	PNF	CPT	FO
1					
2					
3					
4					
5					

Lastly, issues relating to Flight Crew reporting tools and the wider safety management process were recorded.

Participants

Workshop participants included airline participants and researchers (SME 1/technology partner1, researchers from Trinity College Dublin (TCD), technology partner 2 and relevant regional human factors partner). In certain workshops, other airlines attended as observers. For example, in Workshop 1, representatives from airline 2 and airline 5 attended. In Workshop 3, representatives from airline 2 attended. Overall, this involved forty two participants: sixteen Pilots, six Maintenance Engineers, three Ground Operations representatives, one Flight Operations representative, three Dispatchers and seven personnel involved in airline safety management activities. In this sense, the workshops

strongly reflect a Flight Crew perspective. For a summary of participants, please refer to Table 3 below.

Table 3: Breakdown of Participants (Study 1)

#	Flight Crew	Cabin Crew	Maintenance	Co-ordinator	Ground Handing	Flight Operations Controls	Dispatch	Safety/ Quality	Total
1	1	1	1	0	0	0	1	2	6
2	4	1	1	0	0	0	1	0	7
3	2	2	2	0	1	0	-	1	8
4	2	0	1	0	0	1	0	0	4
5	7	2	1	0	2	0	1	4	17

4. RESULTS

Active Flight Operations Process

Generic Process Map

In relation to the structure of the Active Flight Operations process, a generic process map emerged for all five airlines. In keeping with the ATA approach, research suggests that the overall flight operation is divided into three process phases; (1) pre flight, (2) flight execution and (3) post flight. Participants associated a series of process sub-phases, with each of these process phases, as defined in Table 4 below. Overall, these process sub phases map to the specification of flight phases, as outlined by the ATA.

Table 4: High Level Process Map - All Airlines (Study 1)

No	Process Phase	Process Sub-phase	Associated ATA Flight Phase
1	Pre Flight	Flight Planning & Briefing	Flight Planning
		Aircraft release and turnaround	Pre-flight
2	Flight Execution	Engine pushback and start	Engine start/depart
		Taxi	Taxi-out
		Takeoff	Takeoff
		Climb	Initial climb
			Enroute climb
		Cruise	Cruise
		Descent, Approach & Landing	Descent
			Approach
			Go Around
			Landing
		Taxi in	Taxi in
		Park & Shutdown	Arrival
			Engine shutdown
3	Post Flight	Report	Post Flight
		Change Aircraft/Prepare For Next Flight	Flight Close

Participants listed a series of tasks performed by different operators, for each of the process sub stages. In relation to Flight Crew, several tasks emerged as critical across the five workshops. These are defined in Table 5 below. In most cases, this reflects either collaborative tasks (i.e task involving communication or coordination with other roles), or tasks where the quality of task performance or task outputs has a bearing on other tasks (i.e. relationships and dependencies). Across the workshops, participants highlighted the importance of two briefing tasks. This includes the pre flight, planning and briefing, and the top of descent briefing.

Table 5: Key Flight Crew Tasks (Study 1)

Process Phase	Process Sub Phase	Key Task	Roles Involved
1. Pre Flight	1. Flight Planning & Briefing	Pre flight, Flight planning and briefing Fuel Decision	Flight Crew Dispatch Co-ordinator Flight Operations Control/Duty Manager
		Combined crew briefing	Flight Crew Cabin Crew
	2. Aircraft Release & Turnaround	Aircraft technical release	Flight Crew Cabin Crew Maintenance Co-ordinator Flight Operations Control/Duty Manager
2. Flight Execution	Descent, Approach & Landing	Top of descent briefing	Flight Crew ATC
		Ongoing flight planning and briefing	Flight Crew ATC
		Communication/coordination with ATC	Flight Crew ATC
		Flying descent, approach and landing	Flight Crew Flight Operations Control/Duty Manager ATC

Alternative Logic for Structuring Flight Operations Process and Associated Performance in Process Framework

Through the course of the workshops, an alternative logic for structuring the Active Flight Operations process emerged. In Workshop 3, participants observed that the functional logic of the process dictates the task requirements of Flight Crew and other operational roles. In

this regard, a number of milestones need to be achieved at different points in the Active Flight Operations process so that the operational outcome is achieved. Participants noted that the achievement of these milestones requires the completion of task activities by different operational roles. It was suggested that the timing of these milestones roughly corresponds to the specification of flight phases, as defined by the ATA.

These ideas were further developed by the attending workshop participants and human factor researchers. The milestones were reconceptualised as process gates. It was agreed that the operational process can be divided into a series of process gates (or critical points). At each process gate, work must be undertaken by different operational agents, so that the process can move forward (i.e. transition from one process gate to the next). The completion of relevant tasks was conceptualized in relation to the achievement of a series of outcomes and/or states. This includes process states, aircraft states, Flight Crew states, broader operational team states, tool states and information states. Overall, the accomplishment of work across all process gates results in the achievement of the operational goal. The following series of tables – Tables 6, 7 and 8 - present the key process gates identified for airlines 3, 4 and 5.

Table 6: Pre-Flight Process Gates (Study 1)

Process Phase	Process Sub Phase	Process Gates/Critical Points					
		Airline Three		Airline Four		Airline Five	
Pre Flight:	Flight Planning & Briefing	1	Crew arrival/check in	1	Crew Check in	1	Crew Arrives
		2	Crew Briefing	2	Transport to aircraft	2	Dispatch
		3	Combined Crew Briefing			3	Crew meeting
		4	Travel to Aircraft			4	Transfer to aircraft
	Aircraft Release & Turnaround	5	Crew At Aircraft	3	Aircraft ready for boarding	5	Arrive at aircraft
		6	Aircraft ready to board			6	Aircraft status/status of process Aircraft ready – technical register of

							airplane
		7	Aircraft Cleared to chock			7	Full Crew Briefing
						8	Cabin ready to board
						9	All doors closed

Table 7: Flight Execution Process Gates (Study 1)

Process Phase	Process Sub Phase	Process Gates/Critical Points					
		Airline Three		Airline Four		Airline Five	
Flight Execution	Engine push back and start	1	Ready to push-back	1	Ready for start up and push back	1	Out of Gate/Off Blocks
	Taxi	2	Taxi	2	Ready for taxi	2	Taxi
				3	Taxi		
	Takeoff	3	Takeoff	4	Takeoff	3	Ready for Takeoff
	Climb	Not Reviewed					
	Cruise	Not Reviewed					
	Descent, Approach & Landing	4	Pre-descent planning/briefing	5	Briefing Before Top of Descent	4	Before Top of Descent
		5	Ready to descend	6	Top of Descent	5	Top of Descent
		6	Commence descent	7	Final state of approach	6	15 minutes before landing
		7	Arrival phase	8	Final decision to land	7	10,000 ft/Sterile Cockpit
		8	Cabin	9	Landing, touchdown	8	At transition

			secured		and roll out		level
		9	Cleared to altitude			9	Initial approach fix
		10	Configuration change			10	Final approach fix
		11	ATC clear to approach			11	1,000 Ft – between 3 or 4 miles before landing
		12	Final Approach			12	Decision height
		13	Landing & Rollout			13	Touchdown and roll out
						14	80 knots / Handover of controls to captain
	Taxi	14	Taxi	10	Taxi to Terminal Parking Position	15	Taxi
	Park and Shut-down	15	Park & Shutdown	11	Aircraft Parked: engine shut down & seat belt sign off	16	Park and Shut-down

Table 8: Post Flight Process Gates (Study 1)

Process Phase	Process Sub Phase	Process Gates/Critical Points		
		Airline Three	Airline Four	Airline Five
Post Flight	Flight Report	Not Reviewed		
	Change Aircraft/Prepare For Next Flight	Not Reviewed		

In mapping operator task activities, task dependencies must be considered. Here, task dependencies refers to relationships between tasks performed by individual operators or by a group of operators (i.e. collaborating on the same task, or producing outputs relevant to each others tasks) at different points in time throughout the process. Two types of task dependencies were distinguished. This includes prior or sequential dependencies and parallel dependencies. Prior dependencies refer to task activities and associated task outputs performed by the same or other operators, which are inputs to next phase of work. Critically, there are two aspects to this. Firstly, this must be considered at a level of task completion. The task needs to be completed so that the process can continue. For example, Flight Crew must obtain the technical signoff of aircraft, before closing the aircraft doors and proceeding with the aircraft push-back. Also, the quality of task performance must be considered. Tasks may be performed but the quality of task performance may be weak. Parallel dependencies concern work undertaken in parallel by another agent which is an input to the operator's task. Certain higher level dependencies, namely process dependencies were also alluded to. A process dependency refers to a relationship between two different parts of a process or two sub-processes. For example, a relationship between the Flight Planning sub process and the Active Flight Operations sub process). This also includes dependencies between two related processes – for example between the Active Flight Operation, and the Line Maintenance process. Underlying these process dependencies are specific task dependencies.

Flight Crew Task

Relationship between task and process

Introduction

Collectively, the five process workshops provided feedback about the relationship between Flight Crew task performance and the design of the Flight Operations process at different levels. This includes a relationship between the Flight Crew task and (1) the Active Flight Operations process, (2) other Flight Operations processes (i.e. the Flight Planning process and the Safety/Quality/Improvement process and (3) broader processes (i.e. Ground Operations and Maintenance).

Active Flight Operations Process

The functional logic of process dictates Flight Crew task requirements. The performance of specific Flight Crew tasks is linked to different process gates. Certain tasks can span a number of process gates, while others span one process gate. However, at a certain point in the operational timeline, work needs to be achieved, so the process can move forward. Here tasks become mandatory from a process stability perspective.

Some of the issues experienced by crew can be attributed to problems arising in other areas of the Active Flight Operation process. In relation to the Active Flight Operation, participants pointed to both parallel and sequential dependencies. In terms of parallel dependencies, it was observed that in many cases a range of different operators are conducting work in parallel. In some cases, certain tasks may be performed collaboratively (i.e. briefing between Flight Crew and Cabin Crew). In other cases, agents may be working on different aspects of the same task (i.e. Flight Crew and Maintenance in regard to technical signoff of aircraft), and are required to collaborate, to achieve task outputs. In both cases, the task performance of one agent has a bearing on the task performance of the other agent. That is, the task outputs of one agent are required inputs for the performance of tasks by another agent. In these cases, communication or co-ordination problems in relation to obtaining task outputs can impinge on task performance. For example, participants noted dependencies related to Dispatch and in particular, the communication of information to Flight Crew relating to operational changes. In addition, participants pointed to dependencies with regard to the aircraft technical release and communication and co-ordination between Flight Crew and Maintenance personnel. Further, dependencies were noted in relation to the exchange of information between Flight Crew and Flight Operations Control/Duty Manager.

Certain sequential process dependencies (i.e. where problems upstream have the potential to lead to problems downstream) were also noted. For example, a rushed briefing, due to ATC delays and/or delays resolving aircraft technical issues, can result in less time for crew to review the approach procedure. This can impact on task activities later in the process. For example, the crew may receive a number of navigation/routing changes at the top of descent, necessitating a re-briefing on the approach plan. Given this, the crew may have insufficient time to fully brief on the Standard Terminal Arrival Procedures. As a result, the crew may have a poor situation picture of the approach procedure to be flown. This in turn can lead to an unstabilized approach. Participants stated that if the crew have sufficient time to brief on the approach procedure at an earlier period as opposed to spending time managing ATC/Maintenance issues, then they might be in a better position to manage the last minute changes requested by ATC.

Interestingly, participants in workshops 3, 4 and 5 observed that the quality of task performance (and associated task outputs) at these different process gates can vary. For example, at the pre-flight stage, Flight Crew may perform a weak briefing. Although the task is completed, the quality of task performance may be unsatisfactory. This can result in problems later in the process (i.e. approach and landing). This is discussed in more detail in later sections.

Other Flight Operations Processes

The findings of the process workshops also indicate a relationship between Flight Crew task activities and the task activities of other agents involved in broader Flight Operations processes (i.e. Flight Planning and Safety/Quality/Improvement Process).

Across the workshops, participants observed that issues which arise in the Active Flight Operation often result from problems originating in the other two flight operations sub-processes. This is in addition to a range of internal (i.e. crew status, aircraft technical status etc) and external problems (i.e. weather, traffic, passengers etc) that can occur in real-time.

In relation to the Flight Planning process, Flight Crew participants observed that weaknesses in aircraft pairing and rostering often result in problems at the dispatch stage (i.e. crew/aircraft availability). In relation to the Safety/Quality/Improvement process, both Flight Crew and Cabin Crew participants remarked that as a result of weaknesses managing reports information provided by operational crew in relation to operational and safety issues, crew often encounter the same problems on a daily basis.

Broader Processes

Participants also alluded to problems arising in certain wider airline processes (i.e. Maintenance Process), along with certain external processes (i.e. Air traffic management process), which impinge on Flight Crew.

In relation to other airline processes, this refers to the aircraft turnaround and release process, which is part of Line Maintenance Processes and an input to the latter stages of both the Flight Planning and the Dispatch process. Further, other Line Maintenance processes are relevant to the Flight Planning Process (i.e. daily, weekly and monthly checks). Again, certain issues experienced by crews can be attributed to difficulties arising in these other processes. Typically, if aircraft maintenance issues arise in the short-term, they are managed by Flight Operations Control, either prior to the dispatch of the flight, or in parallel to the dispatch of the flight. Usually this relates to aircraft changes. During the aircraft turnaround, delays can occur in relation to resolving aircraft defects that arise in a previous flight. These are either resolved, or there is an aircraft change. Either way, these delays have consequences for Flight Crew.

In relation to other external processes, this refers to the Air Traffic Management process. This includes task activities pertaining to two sub processes - namely processes concerning (1) flight planning and approval of airline Flight Plans and (2) air traffic management (i.e. real-time separation of aircraft handled by ATC Controllers).

According to participants, flight planning issues are typically resolved during the Flight Planning process. The Flight Plan approved by Eurocontrol takes into account air traffic projections and so forth. However, shortly before the dispatch of a flight there may be ATC

restrictions given congestion or poor weather. As such, Eurocontrol can request updates to a filed Flight Plan, shortly before the dispatch of the flight. This can result in revisions to the Flight Plan. Further, changes to departure windows or clearances are often requested shortly before push-back, given real-time air traffic flow issues. For example, there may be a back log of incoming landing traffic, impacting on the windows available for takeoff traffic. Flight Plan changes can also occur during the execution of the flight. Traffic flow management problems can result in ATC requesting late routing changes, requiring Flight Crew to re-brief on the plan during the actual descent.

Task Allocation

Process mapping activities revealed that Flight Crew tasks are allocated according to rank (i.e. Captain and First Officer) and role (i.e. Pilot Flying and Pilot Monitoring). However, depending on the task context and workload demand, there is often a degree of flexibility in term of task allocation. Nonetheless, workshop feedback suggested that in Airlines 1, 2 and 5, roles are more tightly defined and certain tasks are performed by the Captain only.

Team Performance Requirements

Flight Crew collaborate with a range of operational agents at different points in the process. Table 9 provides an overview of these different human roles in relation to particular process gates.

Table 9: Flight Crew Co-ordination with Different Agents at Specific Process Gates (Study 1)

#	Process Phase/Timeline	Process Sub Phase	Critical Point / Process Gate	Communication/Co-ordination (Other Roles)
1	Pre Flight	1 a: Dispatch	Crew Arrive	Cabin Crew
			Flight dispatch/briefing	Flight Operations Control (If Required) Dispatcher (If Required)
			Combined Crew Meeting/Briefing	Cabin Crew
		1b: Aircraft Release & Turnaround	Aircraft technical status	Previous Crew (if aircraft change) Maintenance Co-ordinator Fueller

				Cabin Crew ATC/Ground Control Flight Operations Control (If Required)
			Doors Closed	Cabin Crew ATC/Ground Control Flight Operations Control (If Required)
2	Flight Execution	2a:Push-back, Taxi & Takeoff	Ready for push-back	ATC/Ground Control Tow truck driver and walker
			Taxi	Tow truck driver and walker ATC/Ground Control ATC/Tower
			Ready for takeoff	ATC/Tower
			Takeoff	ATC/Tower
		2b:Climb	Initial Climb Complete: 10,000ft	ATC/Tower ATC
			At Cruise Altitude	ATC Cabin Crew
		2c. Cruise	Navigation/Routing Checks	Cabin Crew ATC Flight Operations Control
		2d. Approach & Landing	Preparation for descent: Approach briefing	ATC Flight Operations Control
			10,000 ft/Sterile Cockpit	ATC/Approach
			Final Approach Fix	ATC/Approach
			1,000 ft	ATC/Tower
			Decision to land	ATC/Tower
			Landing & Rollout	ATC/Tower

				ATC/Ground Control
			Taxi to gate	ATC/Ground Control Ground Marshaller Driver of Follow Me Jeep
3	Flight Review & Report		Complete Flight Report	Cabin Crew
			Exit Aircraft/ Start Next Flight/Handover to Next Crew	Cabin Crew Next Crew (if aircraft change) Flight Operations Control (If Required)

Flight Crew collaboration with certain roles emerged as critical. During the pre-flight stage, this includes the Co-ordinator, Dispatch and Flight Operations Control/Duty Manager function. During the flight, and specifically at the landing phase, this includes Flight Operations Control/Duty Manager.

Management of Operational/Environmental Threats & Risk

Throughout the workshops, participants referred to the concept of flight threats. Flight threats were conceived as issues or problems that arise either before or during the course of the operation that can have an adverse impact on the operation unless they are appropriately managed by crew. During the workshops, participants listed typical blockers/threats that arise at different points in the operational process. In so doing, participants distinguished between operational threats (i.e. aircraft changes, aircraft technical status, crew availability, delays, and information not available) and environmental threats (i.e. weather and complex terrain). Certain threats can be identified before the flight (i.e. weather, aircraft and technical issues). However, others arise during the course of the operation (i.e. poor weather, ATC flight plan changes and Pilot illness).

In workshops 2, 3, 4 and 5, participants referred to the concept of risk. As reported by participants, certain flights involve the management of more or less threats. Flights with a high number of threats, or threats that are serious in nature are generally considered to have a higher risk rating that those with less threats and/or less serious threats identified. It is essential that crew both identify and manage threats, both at the pre-flight, flight planning and briefing stage, and throughout the course of the operation. In explaining this, participants referred to the 'Threat and Error Management' (TEM) framework.

Use of Procedures

Throughout the workshops, participants noted that procedures are important from a safety perspective. Nonetheless, participants remarked that on many occasions, procedures are

not followed. Although this can be attributed to crew complacency, this is not always the case. Often, the crew improvise procedures according to the particular context, or do only what is necessary to keep the process moving forward. Across the airlines there seems to be an unofficial world of how things normally go. As stated by one *participant "Although this is not in line with procedures, it is in line with the practice that is considered appropriate by operational personnel"*. Lack of standardization and optimisation of procedures was specifically relevant in relation to Airline 2 and Airline 5. This mostly concerns procedures for the fuel decision, the pre-flight, flight planning and briefing task, airport taxi, and tasks performed during the descent, approach and landing flight phase. Participants representing Airline 2 observed that this practice is not openly discussed. However, participants from Airline 5 suggested that there is a general acceptance of this in their airline, and that these matters are openly discussed. The consensus view from Airline 5 participants seemed to be that the informal system works well, and that they are safe, even if procedures are not strictly followed. One crew member noted *"If procedures were absolutely followed the aircraft would not takeoff"*. Another commented *"There are different ways to achieve critical milestones – this can involve workarounds"*. *"If they perceive that it is better to do it a different way, then they do this"*. This participant went on to say *"Actual work involves improvisation"*. Participants from Airline 5 observed that this specific attitude to procedures could be partly attributed to cultural factors.

Participants noted that in certain situations it is difficult to follow procedures, given different levels of operational and environmental complexity. During the workshop with Airline 2, the problem of following procedures was discussed in relation to certain airports/environments where it is difficult to follow the stable approach criteria. Here a senior Captain who is also Head of Procedures commented that *"Crew actions may deviate from standard operating procedures but are the right thing to do given an understanding of the specific operating environment and situation/circumstances"*. This comment was further elucidated in relation to problems interpreting and evaluating the airline's LOSA evaluation report.

In relation to Airline four, Flight Crew highlighted the importance of the Pilot role and in particular, the application of crew expertise/experience. A Senior Captain from Airline 4 commented that *"Some people in the industry feel that if Pilots don't follow SOP then they are violating the rules – it is not as simple as that"*. This Captain noted that standard operating procedures do not always apply in certain contexts/situations. *"The role of the Pilot is to ascertain when and how to improvise SOP to optimise the situation"*. This requires considerable expertise. The Captain remarked that standardization is good, but not absolute. Similar views were expressed by the Flight Crew representatives of Airline 3. Participants noted that given salary constraints, the airline is not attracting senior crews. For them, lack of experience on the flight deck presents a serious safety threat.

Tools & Information

Overall, the workshops did not capture detailed information about tool usage. Nonetheless, certain tools emerged as important – in term of frequency of use and the information provided. This includes the Flight Plan, the Technical Log, and specific communication tools such as Very High Frequency (VHF) Radio, and the crew member's mobile phone.

Flight Crew participants stated that if they have sufficient information, then the process can move forward. However, many problems related to information/information flow were noted. Across the workshops, participants pointed to a general problem with the availability, quality (i.e. accuracy and reliability), timeliness and communication of information. This concerns (1) general information about the status of the process/operation, and (2) specific task based information either relevant or necessary to the completion of particular role task actions. Specifically, a number of information gaps were highlighted. Across the workshops, participants noted that they do not always get the latest information related to the status of the aircraft/process, or task actions of other members of the operational team. For example, Flight Crew participants remarked that they rarely obtain information related to the technical status of aircraft in the dispatch briefing. Although both Maintenance and Dispatch have systems to record this information, this information is not always up to date. Further if it is available, it is not provided to Flight Crew. Incomplete Flight Plans or out of flight information (given weather or the ATC situation) seems a common problem.

Certain information is dynamic and subject to change (i.e. weather information, passenger information and aircraft load information). Participants emphasized that it is important to manage updates in relation to this. As reported, sometimes it is difficult to contact the Co-ordinator to obtain the latest information relating to passenger or cargo/baggage load, which is necessary for the completion of weight and balance calculations. Flight Crew are often required to update weight and balance and performance calculations given load changes. As noted, this information is either provided through ACARS, or in person (i.e. a printed copy of the Load Sheet or Load Information Report).

In relation to Airlines 3 and 5, participants reported problems relating to obtaining information about aircraft changes or flight delays. The incoming flight may be delayed or there may be a technical problem – both requiring a change of aircraft. The Flight Operations Control department may have decided to make a change. Regularly, there is a delay in communicating this information to crews. As reported by one participant: *"The Flight Crew are often last people to obtain this information"*. This participant went on to state: *"If information about changes is communicated earlier rather than later to crews, then the specific changes are more easily managed"*.

Pre Flight, Flight Planning & Briefing Task

Throughout the workshops, Flight Crew participants stated that the management of complexity is a central role task function. Critically, CRM strategies are used to manage the different levels of complexity that crew encounter on a daily basis. Central to this, is the execution of briefings, and in particular, the execution of the pre-flight, flight planning and briefing task. As reported by participants, Flight Crew briefing activities at the pre-flight stage assist Flight Crew in terms of the management of complexity.

Across the workshops, Flight Crew and Cabin Crew participants emphasised the value in being briefed or prepared in relation to workload management and problem solving. As one participant noted, *"If you are well briefed, then it becomes easier to deal with problems when they arise later in the flight"*. According to participants, to be prepared or briefed involves reviewing plans and associated contingencies, and being aware of potential threats. This allows crews detect future problems or pick up on errors previously made.

Further, participants consistently reported on the significance of this task, in terms of cementing team concepts. It was observed that a good briefing sets the tone for flight in terms of level of teamwork/joint decision making.

Consistently, participants alluded to issues related to procedural non compliance. Depending on the complexity of the environmental/flight and operational situation, and the crew's familiarity with the route, the crew will allocate more or less time to the briefing. Frequently a minimal briefing is performed. As reported by a First Officer from Airline 5, *"Briefings frequently fail to follow best practice guidelines as relayed in CRM training"*.

Across the workshops, participants remarked that reductions in turnaround times have resulted in less time for crew briefing.

Participants consistently referred to many informal work requirements in relation to the execution of this task, which are currently not captured in airline SOPs. This includes informal information gathering processes such as the informal communication activities with Flight Operations Control, Dispatch, Maintenance and the Fuelling Agent.

In the case of Airline 2 and Airline 5, participants stated that specific TEM practices are incorporated in crew briefings.

There was much variation in the nature of the dispatch process across the airlines. In relation to Airline 1, the dispatch is conducted in person with the Dispatch Officer for all flights. Flight Crew obtain a briefing envelope which contains all relevant information. Also, the Flight Crew have access to computers with specific applications (i.e. real time weather and predictions), should they require additional information. In the person to person briefing, weather and routing issues are discussed. Further, the fuel figure is discussed and agreed.

During turnaround, updated Flight Plans are delivered in to Flight Crew by the Co-ordinator either in person, or using ACARS. In regard to Airline 2, the dispatch process is automated. Crews login to a software package and print the relevant documentation. If fuel changes are requested, a message is automatically generated to the Fueller. Nonetheless, this airline experiences considerable flight plan changes, due to the local ATC environment. Flight Plan updates in relation to routing are often required both shortly after the crew sign in, or up to thirty minutes before the scheduled takeoff time. If crews are in the aircraft, this is communicated via ACARS. The same process also applies at remote locations. If changes are made during the flight planning period, the Dispatcher contacts the Flight Crew. The Dispatch process for Airline 3 was similar to Airline 2. The team access a computer to perform flight planning tasks and print relevant documentation. If later flight sector plans are available, crews will print these too. However, often this is not the case and Flight Plans for later sectors are hand delivered to crew (i.e. agent at outstation). The dispatch process for Airline 4 was similar to Airline 1. A person to person dispatch is conducted with the Dispatch Officer, who has prepared all relevant printed material. That said, crews do not print any additional information (i.e. weather). Fuel and routing is agreed and the Flight Plan is signed off. Interestingly, this airline has a dedicated Navigation Department which co-ordinates with the department in preparing Flight Plans and updating Flight Plans in real-time, if last minute re-routing is required.

Airline 5 has a different dispatch process for short and long haul. In short haul, the dispatch process is automated (like Airline 2). Crews receive an envelope which contains all information relevant to their flight. However, unlike Airline 2, if the crew decides that additional fuel is required, then they must contact the Dispatch Officer, either in person or over the phone. Further, if the flight has a medium or high risk level – given complex weather issues – a person to person briefing with Dispatch is required. In long haul, the dispatch is conducted in person (similar to Airlines 1 and 4).

It was suggested that the presence of the Dispatcher and associated communications (i.e. process design in Airline 1, Airline 4 and Airline 5) enhances crew briefing and situation assessment activities. Yet, participants observed that this can have a negative impact on the First Officer role. As shown, the co-ordination and planning/briefing activities mostly involve the Captain and the Dispatcher. In this sense, there is less space for the First Officer to speak up and make decisions. In the case of the electronic Dispatch process for routine flights (i.e. Airline 2 and 4), and the paper Dispatch process for routine flights (i.e. Airline 5), participants stated that the absence of a third party in these scenarios – however routine - presents its own problems. If the Captain is too authoritative, the First Officer can be less involved in decision making activities. Here, participants pointed to the benefit of collaboration with either Dispatch and/or Flight Operations Control. Nonetheless, participants noted that in such cases, the First officer should deploy CRM techniques and *'speak up'*.

Across all workshops, Flight Crew participants stated that CRM problems can lead to weaknesses in the execution of crew briefings. Further, crew briefings are often hampered by difficulties obtaining key information at the right time. In this respect, participants alluded to difficulties obtaining information from relevant operation roles, and the existence of many informal processes for gathering information.

During the workshops, the researcher questioned participants as to the characteristics of a good briefing. It was suggested that a good briefing is characterized by the quality of team situation assessment and the overall team concept. Participants stated that the quality of briefings varies, and that really good briefings are more the exception than the rule.

Further, the researcher questioned how crew ascertain whether or not a good briefing had been made, and as such, whether the briefing was complete. Consistently participants reported that a briefing is complete when all salient information related to the task/process timeline had been discussed and agreed by both Flight Crew members. Further, the Captain usually asks the First Officer whether or not they have anything to add, and this marks the end of the briefing. During Workshop 5, Flight Crew participants referred to the introduction of a new CRM briefing tool, developed by the airline's CRM department, to support the assessment of threats and team formation, at the pre-flight, flight planning and briefing stage.

During the process workshop with Airline 2, participants alluded to the requirement to perform a special briefing for routes involving a complex approach procedure. By way of example, the Head of Procedures referred to the approach procedures for certain airports in Northern Norway such as the Alta approach.

Human Factors Issues

Facilitators

Briefings

As noted previously, participants consistently highlighted the importance of briefings in relation to workload management and team formation. This includes two formal briefings (i.e. pre flight and top of descent) and ongoing informal briefings throughout the flight.

Teamwork

Across the workshops, both Flight Crew and Cabin Crew participants emphasized the importance of working as a team and having common goals. This relates to the immediate flight team (i.e. Flight Crew and Cabin Crew), and to the other operational roles involved in the flight (i.e. Co-ordinator, Load/Ground Handling and Operations Control). In addition, it concerns the relationship between Flight Planning personnel and personnel involved in the

Active Flight Operation. In this regard, Flight Crew participants emphasized the importance of establishing a combined flight team, setting common goals and establishing communication/co-ordination procedures. As reported, this is typically established in the pre-flight, flight planning and briefing session.

Blockers

Operational & Environmental Complexity

Flights are characterized by different levels of operational and environmental complexity. Throughout the workshops, participants stated that high levels of operational and/or environmental complexity, can impact negatively on task performance.

Procedures Design

Several weaknesses in terms of the design of the existing Flight Operation process were identified by Flight Crew participants at the workshops. Critically, it was noted that these process deficiencies directly impact on Flight Crew task performance.

Across the workshops, participants noted that many communication/co-ordination practices necessary to the achievement of the operational goal, are not formally documented in procedures. As a result, Flight Crew often experience difficulty sharing necessary task support information with other operational agents. As noted earlier, participants often engage in informal and opportunistic information gathering practices, to obtain the necessary information.

In addition, participants highlighted weaknesses in relation to the communication of safety feedback, along with more general information about the safety management process, to Flight Crew. It was suggested that low reporting rates can in part be attributed to these poor feedback mechanisms.

Other Issues

Other issues raised by participants include:

- Problems accessing paper tools in the cockpit (i.e. Flight Plan, Maps and Reports)
- Flight Crew participants pointed to several issues in relation to Flight Crew/ATC communication/co-ordination
- Problems communicating with Maintenance and/or aircraft technical issues impinge on Flight Crew task workflows and workload
- Cabin Crew interruptions impinge on task workflows
- Commercial pressure has negatively impacted on flight operations
- Issues related to crew diversity must be managed.

Performance Monitoring Tools

Workshop feedback indicates that the airlines use a range of paper based and technology tools to gather information about operational performance and to evaluate the overall safety status of the operation. Overall, this links to broader safety management processes. Table 10 provides a summary of the different performance monitoring tools used by the different airlines.

Table 10: Performance Monitoring Tools (Study 1)

Tool	Airline 1	Airline 2	Airline 3	Airline 4	Airline 5
Air Safety Reports (ASR)	Y	Y	Y	Y	Y
Flight Data Monitoring (FDM)	Y	Y	Y	Y	Y
Line Checks	Y	Y	Y	Y	Y
Occurrence Reports	Y	Y	Y	Y	Y
Authority Reports	Y	Y	Y	Y	Y
Simulator Recurrent Training/Checks	Y	Y	Y	Y	Y
Custom HF Reports	Y	Y	Y	Y	Y
Custom Questionnaires/Feedback	Y	Y	Y	Y	Y
Line Operations Safety Audit (LOSA) or adaptation of same	Y	Y	Y	-	Y
Non Technical Skills Evaluation (NOTECHS) or adaptation of same	-	Y	Y	-	Y
Formal Feedback Chats/Sessions with Crews	-	Y	Y	-	Y
Informal Feedback Chats/Sessions with Crews	-	-	Y	-	Y
Roster Feedback	-	-	Y	-	Y
Risk Management Tool Concept (In progress)	-	Y	Y	-	Y
LOFT (Line Oriented Flight Training) / LOS (Line Oriented Simulations)	-	-	-	-	-
Line Oriented Assistance System (LOAS) or an adaptation of same	-	-	Y	-	-

Safety Walks	-	-	Y		-
Specific Grading and Assessment Tool	-	Y	-	-	-
Confidential Human Factors Incident Safety Reporting System (CHIRP)	-	-	-	-	-
British Airways Safety Information System (BASIS)	-	-	-	-	-

Participants observed that the use of certain tools is mandated by the authorities (i.e. FDM, ASR, Line Checks and Authority Reports). For this reason, these tools are used by all airlines. Custom reporting systems such as feedback questionnaires have been developed by all airlines. Certain airlines have modified existing tools such as the Line Operations Safety Audit (LOSA), to fit their own agenda.

Across workshops, participants reported a no blame culture. Yet, it was also observed that near misses are frequently unreported. Consistently, Flight Crew participants alluded to problems accessing reporting forms. Further, participants referred to data input problems (i.e. slow input) – given the paper nature of certain forms. Only a few airlines use/or have used communication sessions (either formal or informal) to elicit safety feedback and/or improvement recommendations. In the fifth workshop, both the Safety Manager and Flight Crew participants referred to a new voluntary reporting tool developed by the airline, which captures reports information in a format inspired by the TEM framework.

Throughout the workshops, Flight Crew participants acknowledge fears concerning the use of FDM data and sanctions for non compliance. In workshops 2 and 3, participants noted that FDM data is not integrated with reports information (both voluntary and mandatory). As such, there is a gap between the 'what' and the 'why'. Other performance monitoring tools such as LOSA have been greeted with mixed reactions. Feedback from Airline 1, 2, 3 and 5 was positive in relation to the emphasis on de-identifying data in LOSA evaluations. However, the Head of Procedures at Airline 2 observed certain problems the airline had in relation to the evaluation of performance using the LOSA framework.

Consistently, Flight Crew participants reported difficulties obtaining feedback concerning the status of reports filed. Also, participants reported a lack of feedback about the status of reports and associated safety/improvement activities. Lastly, across the workshops, participants reported a lack of transparency about the broader safety management process which underlies reporting.

Participant Recommendations for Improvement

At a high level, participants recommended improvements to system information flow, both in relation to (1) information about the status of the operation/process, (2) role/task information

and (3) feedback regarding the nature of the performance/safety management process and the use of reports.

Consistently, Flight Crews recommended that the time between flights be extended to ensure that Flight Crew have adequate time to perform the pre-flight briefing. Further, participants suggested that Flight Crew would benefit from enhanced information at the pre-flight stage. The particular nature of this information was not specified.

Throughout the workshops, it was suggested that the airlines might improve their reporting systems, so that they would obtain a picture of routine performance and not just 'angel' performance. Further, it was suggested that a non punitive reporting model should be followed. It was also suggested that the airline should facilitate informal information exchanges between crews, so that crews learn both (1) from each others experiences and (2) from more experienced crews. Specific strategies for this were not suggested.

Flight Crew suggested that the Load Sheet be automatically sent to crews via the ACARS system instead of forcing manual print-outs. It was suggested that cockpit technology be improved so that crews obtain an early picture of the situation (i.e. weather, NOTAMS and status of ILS) at the destination airport. Across the workshops, Flight Crew participants recommended the introduction of intelligent taxi guidance systems – showing routes, NOTAMS and ground traffic. Crews also noted that electronic navigation charts would be useful (i.e. faster access, easy to update etc). In relation to Airline 2, it was suggested that the EFB should provide electronic access to several tools and information resources currently available in paper format. This includes the Flight Plan, the Technical Log, the Load Sheet and performance calculations. In relation to Airline 2, it was also suggested that Flight Crews obtain NOTAMS information via the ACARS system. Airline 2 participants recommended that Controllers should be able to downlink the actual aircraft 4D trajectory (which might be different to what was filed in the Flight Plan) to the ground, so they have an appropriate expectation of how the aircraft will behave. In relation to Airline 2 and Airline 5, participants indicated that many improvements might be made to the ACARS system and that a second generation advanced ACARS would be most welcome. At a baseline, crews suggested that all aircraft be fitted with ACARS systems. In relation to Airline 2 and 3, both Flight and Cabin Crew suggested that similar rules in relation to meal breaks, duty time and roster entitlements should apply for both Flight and Cabin Crews. Flight Crew participants noted that standardization of English usage in aerospace domain should be enforced.

Both Flight and Cabin Crews recommended additional CRM training for all crews, and potentially combined CRM training. This might focus on communication/coordination requirements both before and during flight, and providing a picture of the performance requirements of different roles and their constraints. Further, it was suggested that explicit CRM procedures should be provided for different operational areas. It was also

recommended that Flight Operations schedule cockpit and cabin crew together, to foster team concepts. This was especially relevant for Airline 2. Participants noted that crews should receive training and associated guidance material in relation to standard crew errors and best strategies for managing problems when they arise. Also, Flight Crew participants recommended that briefing procedures be enforced.

5. DISCUSSION

Process Mapping

Mc Donald's (2005) process mapping methodology was adapted in these process workshops to elucidate the relationship between task and process. In general, this approach proved very useful. This has resulted in a new framework for conceptualizing Flight Crew task activity and the task activities of other operators that interface with Flight Crew during the course of the operation. This new 'process based' logic goes beyond the existing ATA Pilot centric approach - providing a richer explanation of Flight Crew task activities. Specifically, it points to the collaborative task requirements of the process and the information flow logic embedded in this.

Process mapping illuminated certain failings in relation to existing process/procedures design, which impact on Flight Crew. Existing airline SOPs fail to provide a complete description of operational activity. The crew are involved in many informal co-ordination/information sharing tasks with other operational personnel, currently not defined in SOPs. Given these oversights in the existing process design, Flight Crew often experience problems obtaining information from other roles, in a timely fashion. This is especially the case at the pre-flight, flight planning and briefing stage.

The introduction of low cost operations has led to a number of process changes impacting on Flight Crew task performance. This includes the introduction of maintenance on request processes (impacting on Flight Crew/Maintenance information sharing practices). Further, reductions in crew briefing times at the pre-flight stage, has impacted on the time available for briefing.

Moreover, certain weaknesses in relation to the provision of feedback regarding the analysis of safety reports, and the nature of the SMS process were reported.

Potential improvement solutions necessitate changes at different levels including process design, task design and the design of task support tools. This includes (1) the provision of enhanced task support to Flight Crew at the pre-flight stage, (2) extending the time allocated to Flight Crew briefing at the pre-flight stage, (3) the introduction of electronic voluntary reporting tools, (4) the provision of feedback to Flight Crew in relation to reports filed, (5)

more transparency in relation to the nature of the safety management process and the use of reports, (6) overall improvements in the analysis and communication of airline safety information to relevant airline functions, and (7) the introduction of combined Flight Crew and Cabin Crew training.

However, the process mapping approach did not support a detailed analysis of the specific task problems encountered by Flight Crew in relation to the execution of the pre-flight planning and briefing task. This requires further research.

Implicit in this approach is the identification of new processes supporting enhanced information sharing across operators. However, this approach does not focus on the identification of the technology requirements to support this. This necessitates additional research - focusing on the design of existing Flight Operations processes, and in particular, on the relationship between these processes and Flight Crew task performance. User interviews and observations might be used for this purpose. Moreover, participatory methods might be used to assist the identification, modelling and evaluation of new tool requirements.

Flight Crew Task Performance Model

Introduction

Overall, this research illuminates the socio-technical nature of Flight Crew task. In this respect, several socio-technical dimensions emerged as significant. This includes: the relationship between task and process, the role of context, team performance aspects, and the use of tools and information. This research also points to the complex role of procedures in crew operations.

Socio-technical Aspects

Relationship between task and process

The findings of the process workshops bridge certain gaps in the literature concerning the relationship between Flight Crew task performance and process design. An analysis of the collective workshop findings suggests that the relationship between task and process can be analysed on several levels. This includes the relationship between the Flight Crew task and (1) the Active Flight Operation, (2) broader Flight Operations processes (i.e. Flight Planning and the Safety/Quality/Improvement process), and (3) other non Flight Operations processes (i.e. ATC, Maintenance and Ground Operations).

As shown, the functional logic of the process dictates both Flight Crew task activities and the task activities of other operators who interface with Flight Crew. This has resulted in a new way of conceptualizing Flight Crew task activity. Unlike what is described in the Flight Operations literature, a process centric view of the Flight Crew task activity is proposed.

Context/environment

In support of the research of Loukopoulos, Dismukes and Barshi (2003), context has an impact on Flight Crew task performance. The flight is a dynamic process subject to contingency. Moreover, all fights are characterized by different levels of operational, environmental and team complexity. Overall, this creates different task demands for both Flight Crew and other operational agents. This has an impact on the ability of Flight Crew to execute SOP's at fixed points in the process, and on workload. Thus, procedures are often optimised to manage different levels of complexity. As highlighted in the example of the Alta approach, the management of this complexity requires much expertise on the behalf of the crew. This coheres with the research of Johnson (2003) in relation to the importance of expertise, and the optimisation of procedures in different contexts. However, this is not to minimise the important role of procedures from a safety perspective. Nor is it to suggest that procedures are never followed. As highlighted in the process workshops, crew complacency in relation to the requirement to follow procedures and/or procedural non compliance is perceived as a safety threat. Thus, such optimisation of procedures is carefully considered, and has a safety basis.

Further, in keeping with the findings of Loukopoulos, Dismukes and Barshi (2003), Flight Crew task performance is impacted by the task performance of other operational agents. Crew do not always obtain key information inputs from other agents at the right time. As such, task performance does not always follow the workflow descriptions defined in SOPs. Rather, many tasks are performed both opportunistically and concurrently. Moreover, research highlights how CRM and TEM training concepts are applied in the operation, in relation to the management of context. As shown, the execution of crew briefings is essential to this.

Team picture

Flight Crew operate at the sharp end of the operation in relation to the management of different levels of complexity. This necessitates strong collaboration between Flight Crew and different human operators. Arguably, Flight Operations manuals fail to provide an accurate account of the nature of this team support. Overall, there is a disproportionate focus on ATC and the frontline team (i.e. Flight Crew, Co-ordinator, Cabin Crew, Maintenance). As evidenced in the process workshops, Flight Crew co-ordination with certain back office personnel (i.e. Flight Operations Control and Dispatch) is fundamental to the successful achievement of both the safety and operational goal. Thus, feedback from the process workshops supplants existing team descriptions. Further, process mapping highlights the underlying social process mechanisms necessary to the achievement of the functional process. Crucially, the crew depend on information inputs from a range of team agents as

outlined above. Critically, this involves the use of informal co-ordination/communication mechanisms and task workarounds.

Use of Tools

The importance of several Flight Crew task support tools was also emphasized. This includes the Flight Plan and several communication tools (i.e. VHF Radio, ACARS and the crew member's mobile phone). In relation to the latter, these tools are critical to both formal and informal information sharing practices.

Research highlights the key role of these tools in relation to the communication of necessary task support information. As shown, lack of information and/or incomplete information impinges negatively on task workflows and workload management.

Potentially, certain aspects of both sets of tools might be optimised in terms of the introduction of an improved electronic flight planning and briefing tool. This requires further research.

Use of Procedures

Workshop feedback highlights the complex role of procedures in operations. Procedures are required from a safety perspective. Yet, airlines cannot always rely on the professionalism of their crew, in terms of adhering to procedures. Consistent with the research of Helmreich, Klinect and Wilhelm (1999) and Klinect, Murray, Merritt & Helmreich (2003), it appears that Pilots are often injudicious in relation to ensuring that SOPs are followed. In keeping with the findings of Helmreich et al. (1999), this is often a result of crew complacency. However, this is not always the case. Critically, process mapping feedback highlights another perspective on Flight Crew use of procedures which is not reported in the literature. As emphasized by participants from Airline 2, 4 and 5, the crew often improvise procedures, in order to keep the process moving (i.e. to ensure the stability of the process). Further, sometimes procedures cannot be strictly followed, as illustrated in the case of the Alta approach, as relayed in the process workshop with Airline 2. Consistent with the research of Johnston (2003), Pilots often draw upon their own expertise in identifying how best to optimise procedures in order to manage the complexity of the situation. Research also appears to validate the assertions of Losa (2007), in relation to the identification of weaknesses in process design, which impact on Flight Crew use of procedures. As shown, weaknesses in process design often impact on the crew's ability to follow procedures at a fixed point in the flight operation. In particular, this relates to weaknesses in information sharing between Flight Crew and other roles, which often result in Flight Crew postponing a task.

Thus, the findings of these workshops leave us in a rather difficult position in relation to settling the role of procedures. It would seem that procedures are required. However, Pilots cannot always be relied upon to follow procedures. Moreover, sometimes procedures are not

appropriate or useful, in terms of managing the indeterminacy of the situation. Further, procedures/process design often gets in the way of crew adhering to procedures. In this sense, we are left without a firm anchor. Potentially, the pre-flight, flight planning and briefing task, provides a way forward. That is, the introduction of new tools to support crew briefing at this time, might provide a way of managing this problem. Such a tool might be used to solve certain problems related to flight operations process design such as the sharing of operational information with other stakeholders, which impact on Flight Crew. Further, such a tool might provide crew with the appropriate information to support the assessment of procedures in relation to the particular flight context. This requires further research.

Performance Monitoring & the Requirements for a New Briefing Tool

The five process workshops illuminate certain problems with the design of existing airline performance monitoring methods and tools. Existing reporting tools are difficult to access and time consuming to complete. Further, reporting rates are low and there is often a general lack of motivation in relation to making voluntary reports. This is attributed to certain underlying problems with the existing design of the safety management process. In particular, this pertains to weaknesses in existing feedback processes (i.e. lack of feedback regarding previously filed reports and a lack of transparency about the role of reporting in relation to the broader SMS process). It should however be noted that this feedback mostly reflects the perspective of Pilots. As noted, there was a strong representation from Pilots in the workshops. As such, a potential Pilot bias must be considered carefully. Thus, these findings need to be validated with additional Safety personnel. Further, a more detailed investigation of reporting in relation to the broader safety management process is required.

Some of these problems might be ameliorated by the introduction of electronic reporting tools and the provision of improved feedback loops to Flight Crew. Potentially, the introduction of an improved briefing tool for use by Flight Crew at the pre-flight stage provides a vehicle in which to communicate relevant reports feedback to Flight Crew. Such a tool might relay flight specific safety/risk information to Flight Crew following from the analysis of airline operational and safety data/reports. This in turn might assist Flight Crew CRM/TEM activities. In this way, this tool might make use of safety data, from a Flight Crew task support perspective. This would require changes to existing airline safety management processes and tools. Is this feasible? This warrants more detailed research in relation to the broader safety management processes and tools.

Pre Flight, Flight Planning & Briefing Task & the Requirements for a New Briefing Tool

The pre-flight, flight planning and briefing emerged as a key task across all workshops. Primarily, this follows from several core functions of the briefing task in terms of assisting team building, situation assessment and workload management.

In support of the research of McDonald (2005) and Sachs (1995), it appears that existing SOP's fail to provide an adequate description of task activity. That is, SOP's neglect to describe the many informal information gathering processes, which the crew engage in, to supplement the information picture provided in the current Flight Plan. Critically, these workarounds exist given weaknesses in the existing process design.

It is worth noting that although airlines broadly do things similarly (i.e. albeit minor differences), there was considerable variance in relation to the nature of the dispatch process. This concerns (1) the role of Dispatch, and (2) the use of computers as part of this process (i.e. paper or electronic access to briefing package). Overall, this has an impact on how this task is executed. Thus, process redesign changes must be carefully considered in relation to their impact on this task.

The contents of the briefing package (and specifically the Flight Plan), was for the most part similar across the different airlines. The main differences concerned (1) the format of specific flight plan information and (2) the medium used (e.g. paper or electronic). Two airlines provide additional task support for Flight Crew at the pre-flight stage. Airline 2 provides crew with additional briefing information, for complex flights such as the Alta flight. Airline 5 provides crew with a special pre-flight briefing checklist. Critically, this assists Flight Crew application of CRM/TEM behaviours, while performing the briefing. Potentially, both of these concepts might be extended in terms of the introduction of an electronic briefing tool.

As pointed out earlier, flights are characterized by different levels of complexity and/or risk. Arguably, there are two key implications of this. Firstly, crew should be informed of the risk level of their particular flight, at the pre-flight stage. Secondly, the crew should receive enhanced task support for medium to high risk flights. Existing tools fall short of providing such task support.

Many problems with the execution of the briefing task were reported. This includes: (1) procedural non compliance/procedural drift, and (2) reductions in turnaround times, resulting in less time for briefing. Further, workshop feedback indicates the crew frequently experience problems retrieving the latest operational updates information. Again, this reflects the perspective of Flight Crew. Thus, these points must be considered from other perspectives. Nonetheless, the introduction of an intelligent pre-flight, briefing tool might resolve some of these problems. In particular, such a tool might (1) support crew execution of the pre-flight,

flight planning and briefing task in accordance with SOPs (albeit with reduced time), (2) facilitate the communication of operational updates to crew, (3) provide feedback about the risk status of the flight, and (4) provide additional task support for high risk flights.

6. CONCLUSIONS

The findings of the collective process workshops have resulted in the advancement of a model of Flight Crew task performance in the context of the Active Flight Operations process and other processes which interface with it. Specifically, these workshops demonstrate that the functional logic of the Active Flight Operations process generates particular task requirements for Flight Crew. Further, this functional logic structures Flight Crew task workflows.

This study illuminates the importance of Flight Crew performance of the pre-flight, flight planning and briefing task, in terms of delivering on key operational and safety requirements of the process. In terms of the latter, this includes: the management of complexity, teamwork, team situation awareness and workload management. However, this research suggests that Flight Crew briefings at the pre-flight stage frequently do not follow best practice in briefing as defined in CRM training. Further, this research illuminates certain weaknesses in the delivery of operational and safety information to Flight Crew, at the pre-flight stage.

The process mapping workshops also highlight existing process design problems related to the sharing of both operational and safety information across different Flight Operations functions. Critically, these process design problems impinge on Flight Crew task performance - both generally and in relation to Flight Crew performance of the pre flight, flight planning and briefing task. Thus, process mapping workshops point to certain key requirements of the process in relation to supporting Flight Crew task activity. Firstly, the process should support information sharing across relevant stakeholders. Further, the process should ensure the timely and quality delivery of appropriate information to Flight Crew, at different points in the flight operation. In this way, the Flight Crew task problem is not merely a HCI tool design problem. Rather, it can be conceived as part of a broader process design problem pertaining to information flow across different operational and organisational functions and roles. Potentially, the introduction of a new task support tool provides a way of managing these process design problems. In principle, system information flow improvements might be mediated through the introduction of a new tool assisting Flight Crew performance of the pre-flight, flight planning and briefing task.

Overall a number of caveats should be noted. Process mapping workshops were Flight Crew centric. There were insufficient representatives from Maintenance, Dispatch and Safety. Other role task requirements were examined in terms of collaboration with Flight Crew. The

human factors discussion was quite high level. Many of the issues raised by participants necessitate further exploration in terms of research with (1) Flight Crew personnel (2) Flight Planning personnel and (3) personnel working in the area of Safety, Procedures Design and Training. Potentially, certain issues which arose in the individual workshops may reflect the biases of the attending participants. Process and task relationships were not explored in much detail. In particular, the relationship between Flight Crew task performance (both generally and in relation to the pre-flight, flight planning and briefing task) and the broader Flight Planning process is required. Further, the role of context requires additional elucidation. Lastly, the relationship between Flight Crew task performance and tools/information was not explored in much detail, and requires further analysis.

This Study is the first thesis study. As such, it sets the framework for future thesis studies. In this respect, this study points to several areas requiring further analysis. Firstly, this study points to a conceptualization of Flight Crew task performance, from a socio-technical perspective. Nonetheless, more detail on the shaping influence of these different socio-technical aspects of Flight Crew task performance (i.e. process, team, context, tools and information) is required. In particular, the process based conceptualization of Flight Crew task performance, requires further validation. Collectively, this is explored in the first half of Study 4.

The process mapping workshops illuminate the complex role of procedures in operations. Further research is required in relation to this. Ideally, observation of real world task practice might be undertaken to validate this feedback. This is explored in the first half of Study 4. Further, additional research is required in relation to understanding the use of procedures and the role of briefing, as part of the Alta approach. This is undertaken in Study 3:2.

Research also indicates certain high level dependencies between the Flight Planning process, and Flight Crew task activities. Further, this research highlights the critical role of both the Dispatcher and Flight Operations Control/Duty Manager, in relation to Flight Crew task activities – both generally, and in relation to the pre-flight, flight planning and briefing task. This is examined in more detail in Study 2.

Workshop feedback also indicates certain problems pertaining to existing performance management approaches and tools. In particular, workshop findings point to issues pertaining to the design of Flight Crew reporting tools and reports feedback processes. This research also suggests a lack of transparency in relation to the use of reports as part of the broader safety management process. Given the possibility of introducing flight specific, risk/safety feedback in the flight plan, following from the analysis of safety and operational data, this warrants closer analysis. This is investigated in Study 3.1.

Further, this study highlights the importance of the pre-flight, flight planning and briefing task, and as part of this, Flight Crew use of CRM and TEM strategies. This was particularly highlighted in Workshop 2, in relation to the Alta approach. This is explored in Study 3:3.

Airline 5 has introduced new tools to assist Flight Crew performance of the pre-flight, flight planning and briefing task. These tools suggest a potential way forward for an improved briefing tool supporting all aspects of the pre-flight, flight planning and briefing task. This requires further exploration. This is examined in Study 3:3.

More detailed information about the nature of the pre-flight, flight planning and briefing task and Flight Crew requirements for an improved tool supporting this task is required. This is undertaken in the second half of Study 4.

Study 2: Process Mapping – Flight Planning Process

1. CHAPTER INTRODUCTION

This chapter reports on the findings of the second HILAS study, the Flight Planning Study. This study was undertaken after Study 1, and in parallel to Study 3 and the first part of Study 4. This involved research with Airlines 2 and 5 only.

The objective of this study is to examine in more detail certain issues which arose in the collective process workshops pertaining to the Flight Planning Process. During the five process workshops, Flight Crew participants pointed to the important role of both Dispatch and Flight Operations Control, in terms of (1) collaboration with Flight Crew as part of the pre-flight briefing for high risk flights, (2) the communication of operational updates information throughout the flight and (3) collaborative decision making in relation to the management of flight threats throughout the flight. Participants also identified a series of problems arising in the Flight Planning process, which can adversely impact on Flight Crew task performance. It was suggested that Flight Crew often inherit problems arising from decisions made by both Dispatch and Flight Operations Control either before the dispatch of the flight, or at the dispatch stage. Also, it was suggested that the existing safety management process might be improved to ensure the provision of appropriate safety feedback to Flight Planning personnel, to support aircraft pairing and rostering activities, and the development of the flight plan.

Evidently it is necessary to understand these findings from the perspective of the Flight Planning process, and the task requirements of the different Flight Planning functions. In particular, it is necessary to identify what constraints apply to Flight Planning personnel, how these impinge on Flight Crew task performance and how this might be addressed in terms of the introduction of an improved tool supporting Flight Crew performance of the pre-flight, flight planning and briefing task.

2. INTRODUCTION

The Flight Planning process is structured in terms of three process phases. This includes: commercial flight planning, aircraft pairing and rostering, and dispatch. Little information is available about the commercial planning process and the associated task functions of relevant Flight Planning personnel. The same is true of the aircraft pairing and rostering

process. Further, the flight planning literature does not address the impact of these processes on Flight Crew task performance.

Primarily, the flight planning literature focuses on the Dispatch process and the role of the Dispatcher. Specifically, it provides a description of the task activities of the Dispatcher (1) prior to the formal dispatch of the flight (i.e. the production of the Flight Plan, the signoff of the Flight Plan with ATC/authorities, and updates to the flight plan shortly before the crew arrive), and (2) at the pre-flight stage. However, the shaping influence of both the dispatch process and the dispatch function on Flight Crew task performance is not explained.

The process for producing, filing and agreeing on the flight plan is as follows. The Flight Plan is produced using commercial flight planning systems. As highlighted in Flight Operations manuals, the critical function of Dispatch is to ensure that the crew have an appropriate amount of fuel and that the Flight Plan routing takes into account and/or avoids other traffic. Depending on the status of the route (i.e. if it is a new route or an existing route), a new Flight Plan or a recurrent Flight Plan is filed. Dispatch personnel file flight plans with the relevant air traffic agency for all destinations at an agreed time before the flight. The proposed Flight Plan is reviewed by the air traffic agency and amended as required. Typically, the airline will follow a repetitive flight plan. However, the routing is often modified on the day given weather and/or ATC issues. As such, a revised Flight Plan must be approved by the relevant air traffic management agency. Usually, the Flight Plan is further updated shortly before the flight to take into account the latest 'real time' operational (i.e. aircraft and crew changes) and environmental changes (i.e. weather changes).

Depending on the airline's process for both short and long flights, the Dispatch department will either review the Flight Plan with the Captain and First Officer, or there is an auto-dispatch. The crew can request changes to the Flight Plan if required (e.g. flight level, alternates and fuel upload). This is usually negotiated with the Dispatcher, who in turn follows up any requests with relevant operational roles. If there are any issues associated with the flight (i.e. aircraft technical issues, ATC problems and so forth), the Dispatcher may confer with Flight Operations Control/Duty Manager. However, flight operations manuals do not describe the specific nature of this co-ordination. Following from this, the Dispatcher and/or Flight Operations Control will relay relevant Flight Plan updates to the crew. Again, flight operations manuals do not specify the nature of this process, and the impact of this process on Flight Crew task activities.

The Safety/Quality/Improvement sub-process runs in parallel to the Flight Planning process. As part of this process, Safety and Risk personnel analyse the operational and safety reports completed by the crew at the end of the flight. This information is used to assess the safety/risk status of the operation and to determine any corrective actions required. In principle, feedback from this analysis is relayed to Flight Planning personnel, to optimise the

quality of Flight Planning. However, Flight Operations manuals do not define the nature of this process. As such, it is not clear what information is communicated to Flight Planning personnel, and how this information is communicated. Further, it is not clear how this information is factored into aircraft pairing and rostering activities, and the development of the Flight Plan by Dispatch. This warrants further analysis. In principle, feedback is provided to Flight Operations Control/Duty Manager, to ensure that any relevant safety issues are understood and managed by the Duty Manager on the day. Again, the nature of this process is not specified in airline flight operations documentation.

Moreover, both Safety and Risk personnel analyse relevant safety feedback in real-time. This feedback is relayed to Dispatch and Flight Operations Control/Duty Manager to support the ongoing management of the operation. Where relevant, this feedback is communicated to Flight Crew to support ongoing safety and TEM activities, at different flight phases. Again, little information is provided about the nature of this process and how it impacts on Flight Crew task activities.

3. RESEARCH DESIGN

Objectives

The specific research objectives included:

- To advance a high level map of the Flight Planning process
- To understand the role of Dispatch and Flight Operations Control, and how this impacts on Flight Crew task activities, as part of the Active Flight Operations process
- To understand the relationship between Flight Crew, Dispatch and Flight Operations Control, at the pre flight, flight planning and briefing stage
- To understand the nature of the information flow between the Flight Planning Process and other Flight Operations processes, and associated opportunities for improving this.

Methods

Interviews

Seven interviews were conducted with personnel from both Airline 2 and 5. Overall, these participants were involved in a spread of functions including Aircraft Pairing and Rostering, Dispatch and Flight Operations Control.

Before the interviews, the Researcher developed an interview worksheet for use as part of the interviews. One to one, semi-structured interviews were conducted on site with airline

personnel. Both the researcher and the HILAS airline representative attended the interviews. In both cases, the HILAS representative was a Pilot. On certain occasions, additional HILAS representatives attended the interviews as observers. In regard to Airline 5, some of the participants were not fluent in English. Where required, the HILAS airline representative translated the researcher's questions and/or the participant's answers. At times, the HILAS representative posed the question in the participants native language and discussed the issue, and then explained the response to the researcher (this occurred only on a few occasions). Interview feedback was recorded using pencil and paper.

Before the interview commenced, the researcher explained the interview purpose and reminded participants about the confidentiality of the interview findings. The researcher then explained the nature and objectives of the HILAS project. The overall findings of the process workshops and the first phase of Flight Crew task analysis were then outlined. This included findings in relation to dependencies between the Flight Planning process and the Active Flight Operations process. Participants were invited to comment on these findings. Participants were then asked to describe their role in the context of the broader Flight Planning process and associated challenges. Participants were then questioned about the specific task requirements of their role. This includes what tasks they perform, who they co-ordinate with, how they co-ordinate with the particular roles, tools used and typical task deviations. As part of this, participants were asked specific information flow questions. This includes: where information is obtained, who they send information to, who they obtain information from and information flow/sharing problems. Participants were then invited to demonstrate their existing work tools. Some additional questions were then posed to individual functions. In relation to the aircraft pairing and rostering, the Researcher elicited workflow information concerning the aircraft pairing and rostering process and associated Flight Crew task dependencies. In relation to Flight Planning, participants were asked questions concerning how the roster is produced and how this relates to the broader safety management process. In relation to Dispatch, the Researcher posed questions concerning the production of the Flight Plan, the contents of the Flight Plan, gaps between Dispatcher knowledge and what is stated in the Flight Plan, the handover of the Flight Plan from Dispatch to Flight Crew, and the level of collaboration/coordination between Dispatch and Flight Crew at the pre-flight, flight planning and briefing stage. In relation to Flight Operations Control, the researcher posed questions concerning the real time management of the Flight Plan, and the level of collaboration/coordination between Flight Operations Control and Flight Crew at pre-flight flight planning and briefing stage. Lastly, there was a free-form discussion covering issues pertaining to the participant's work, and how the proposed new HILAS tools might function to address the particular work challenges raised, specifically in relation to information flow improvements.

Participant names and roles were recorded during the research sessions. After the sessions, all transcripts were de-identified (i.e. participant name, but not role).

Observations

Further, two observations of the flight dispatch process and two observations of Flight Operations Control process were conducted with personnel from Airline 5. These observations were used to validate the information obtained in participant interviews. Observations were conducted on site, at the airline's offices. These observations were conducted opportunistically. The HILAS representative approached the people involved and asked permission to observe their work. Observations varied from including (1) only the Researcher, (2) both the Researcher and the HILAS representative and (3) the Researcher, the HILAS representative and other researchers. Where possible, the Researcher took notes during the observations.

Combined Interviews/Observations

Three combined interviews/observations of Flight Operations Control personnel from Airline 2 were also undertaken. During the observations, the participant explained what they were doing as the work progressed. Where possible, the researcher asked questions to clarify issues related to the task activity observed. This occurred during 'down-time' periods, or after the observation. The Researcher took notes during the observations/interviews.

Overall Analysis

Research findings across the two airlines were then analysed. First, a process map was advanced detailing relevant role task actions at different points in the process timeline. Further, research findings were analysed in relation to three core themes. This includes, (1) the relationship between Flight Crew and Dispatch and associated information flow issues, (2) the relationship between Flight Crew and Flight Operations Control and associated information flow issues, and (3) the relationship between Flight Planning and Safety and associated information flow issues. Prior to the development of scenarios and prototypes for the new electronic briefing tool, these research findings were co-related with the findings of the processing mapping study (i.e. Study 1), the Performance/Safety Management (i.e. Study 3;1, Study 3:2 and Study 3:3), and the Flight Crew task analysis study (i.e. Study 4).

Participants

Overall, research was undertaken with sixteen participants spanning a range of Flight Planning functions. This includes Aircraft Pairing and Rostering, Dispatch and Flight Operations Control. A breakdown of participants is provided in Table 11 below.

Table 11: Breakdown of Participants (Study 2)

Method	Airline Ref	Participant Number	Role/Function
Interviews	Airline 2	1	Head of Dispatch
	Airline 2	2	Flight Planning Officer
	Airline 5	3	Flight Planning Manager
	Airline 5	4	Monthly Operations Manager
	Airline 5	5	Daily Operations Manager (Flight Operations Control)
	Airline 5	6	Daily Operations Officer
	Airline 5	7	Jefe De Dia (Flight Operations Control)
Observations	Airline 5	8	Jefe De Dia (Flight Operations Control)
	Airline 5	9	Flight Operations Control Personnel 1
	Airline 5	10	Flight Operations Control Personnel 2
	Airline 5	11	Flight Operations Control Personnel 3
	Airline 5	12	Dispatch Manager
	Airline 5	13	Dispatch Officer
Combined Interviews/Observations	Airline 2	14	Chief of Flight Operations Control Centre (Flight Operations Control)
	Airline 2	15	Maintenance Control Officer
	Airline 2	16	Crew Management Officer

4. RESULTS

High Level Flight Planning Process

Introduction

The critical objective of the Flight Planning process is the production of the Flight Plan and associated allocation of resources. The Flight Plan is progressively defined over the course of the flight planning process. This involves a range of strategic and tactical work in relation

to the production of the Flight Plan. This work can be divided into three overall phases, spanning different process gates. This includes, (1) long term (i.e. 12 to 6 months), (2) mid term (i.e. 1 month before) and (3) short term (i.e. 3 days to 1 hour). A summary of this process is provided in Table 12 below.

Table 12: Flight Planning Process Map (Study 2)

#	Process Phase/Timeline	Specific Timeline	Organization Function	Process Gate / Critical Point
1	Long Term (12 to 6 months before)	12 to 6 months before	Commercial Flight Planning	Publish Strategic Flight Operations Plan (Flight Planning, Crew Numbers, Routing, Aircraft Leasing etc)
		Every 6 months	Human Resources	Crew recruitment
			Dispatch	Agree Repetitive Flight Plans/Routing with Eurocontrol
2	Mid term (1 month before)	1 month before operation	Aircraft Pairing & Rostering	Design Next Months Flight Plan: Aircraft Pairing & Roster Publish Draft Crew Roster for Next Month Review Crew Feedback about Draft Roster Publish Next Months Flight Plan/Roster
3	Short term (3 days to 1 hour before)	Two days before operation	Dispatch	Prepare and Publish Flight Plan
			Flight Operations Control (Crew Management)	Update Aircraft/Crew Pairing for all flights
		24 hrs before operation	Flight Operations Control (Crew Management)	Update Aircraft/Crew Pairing for next day Update Crew Manifest (Crew List) for specific flight
		From 24 hours before operation to 1 hours before operation	Dispatch	Update Flight Plan with latest information (weather, NOTAMS, maintenance, passengers, fuel etc)
			Flight Operations Control Centre (Crew Management, Dispatch & Maintenance)	Update Crew Manifest (Crew List) Update Flight Schedule/Slot Information Make Aircraft Changes (Delays, Maintenance Issues)

Long Term

From a long term perspective, flight planning involves managing (1) flight plan/routing agreements with the regulatory agencies and (2) commercial aspects of the operation (e.g. tickets/passengers numbers/route preferences). Further, it involves resource planning and management (i.e. managing aircraft/fleets, human resources and associated contracts). Every six to twelve months, the commercial department publishes its strategic plan. This includes an analysis of market/passenger demands, existing routes, resources (i.e. crew and aircraft), leasing arrangements, costs and commercial opportunities. As part of this, new routes are suggested. This is reviewed by the Human Resources Department. Depending on resource requirements, the Human Resources Department engages in a recruitment drive. Further, every six months, the Dispatch department agrees both new and repetitive flight plans with the relevant ATM agency.

Mid Term

In the mid term, Flight Planning involves the progressive development of crew rosters and the high level development of the Flight Plan, for all operations. This takes into account ongoing communication/feedback from Safety functions concerning any safety issues that have and/or may have an impact on flight planning. This includes safety feedback, pertaining to crew composition issues, as relayed in crew voluntary reports. On a monthly basis, members of the Flight Operations department identify the best plan for keeping all fleets/aircraft in the sky, while optimising crew resources. Typically the assignment of the cockpit team (i.e. crew composition), takes into account the crew members route experience, along with their experience of a particular aircraft type. The flight planning department usually try to assign the same crew to a series of flights, to support teamwork. In this regard, it was suggested that CRM concepts are built into aircraft pairing and rostering plans. Rosters are published one month ahead of the actual operation. Crews have a number of days to provide feedback about the roster before it is formally signed off.

Short Term

In the short term, flight planning involves the specification and finalisation of individual flight plans, taking into account the latest operational and environmental situation. Overall, this requires the completion of a range of integrated tasks across several operational functions - including Flight Planning, Dispatch, the Co-ordinator and Flight Operations Control. In addition, there is ongoing communication/feedback between Flight Planning and Safety functions pertaining to new safety issues that have emerged or may emerge and require real-time management by Dispatch and Flight Operations Control.

Between forty eight and twenty four hours before the operation, the Dispatch department creates the Flight Plan. In specifying the Flight Plan, the Dispatcher aggregates information

from both flight operations functions (i.e. Flight Operations Control) and non flight operations functions (i.e. ATC, Maintenance and Ground Operations). This includes information related to weather, routing, fuel, aircraft technical status, crew, departure airports and destination airports. Much of this information is directly accessible from the Flight Planning system.

Interviews with monthly planning (Airline 5) and aircraft pairing and rostering (Airline 2), indicate that given certain internal (i.e. aircraft technical status and crew availability) and external contingencies (i.e. weather and ATC restrictions), the Flight Plan is subject to change. Often there are problems pertaining to crew availability, the aircraft technical status and/or, ATC/traffic management. Depending on the operational and environmental situation and associated changes, the Dispatch department will continue to update the plan, up until an hour before the flight. Further, changes are often required at the flight dispatch stage. That is, while the crew are conducting the pre-flight briefing. As part of this, the Dispatcher co-ordinates with Flight Operations Control, to signoff any required changes. Depending on the situation, the Dispatcher or Flight Operations Control will follow up these changes with Flight Crew.

Typically, the Dispatcher on duty obtains information from Safety, in relation to current threats impacting on a specific flight and/or new treats impacting on one or more operations. This information in turn is taken into account in terms of updates to the Flight Plan. Further, this information is relayed to Flight Crew. This process was described as *'ad hoc'* by several participants.

Role Task Functions & Flight Crew Collaboration Requirements

Flight Planning

The Role of Flight Planning is to produce the high level Flight Plan and roster. Flight Planning do not have direct contact with Flight Crew. Nonetheless, they obtain email feedback from the crew, if a crew member has a request in relation to changing certain aspects of the roster.

Dispatch

The dispatch task functions largely relates to the production of the Flight Plan. As highlighted by Dispatch personnel in both Airline 2 and 5, the nature of the Dispatch process varies according to the risk level of flight. Depending on the risk status of the flight, the Dispatcher is required to co-ordinate with Flight Crew, at the pre-flight, flight planning and briefing stage. Primarily this relates to the fuel decision and navigational decisions (e.g. changes to routing/alternates and flight levels). In this way, although the signoff of the Flight Plan is the

Captain's responsibility, the Captain obtains support from the Dispatcher. As reported by one Dispatcher: *"In high risk situations, the pre flight, flight planning and briefing task is very much a collaborative task"*.

The nature of the dispatch process also varies according to the type of flight (i.e. short/long range flights). In Airline 5, the Dispatch process is automated for short haul flights. If crews have problems with the Flight Plan (i.e. in relation to fuel or alternates), they are required to contact the Dispatcher, either using the phone or in person. However, long range flights take the form of a flight review between the Dispatcher on duty, and the Captain and the First Officer. In Airline 2, all dispatch functions are automated (electronic dispatch). Here, crews manually update fuel figures and this information is updated in the dispatch system. As such, fuel requests are automatically sent to the relevant fuel agent. However, if there is a problem, the crew members contact either the Dispatcher and/or Flight Operations Control directly.

Interviews and observations with both airlines highlight the dynamic nature of flight. Specifically, the situation (i.e. ATC windows, weather, aircraft technical status), can change shortly before the flight, while the Flight Crew are performing the pre-flight, flight planning and briefing task. Thus, at this stage, there is often ongoing communication between the Dispatcher and Flight Crew. This communication either occurs in person (if the crew are in the crew room), or over the phone, or using ACARS.

Flight Operations Control

Flight Operations Control is responsible for the management of the day to day operation. The FOC function is active from two days before the commencement of the operation, right through to the completion of the operation. As stated by one participant: *"Decisions made in relation to one flight, take into account the broader operational picture"*. In making decisions regarding a particular operation, Flight Operations Control must factor commercial interests (i.e. passenger numbers and aircraft changes), specific operational issues (i.e. sick personnel and aircraft technical issues) and the environmental situation (i.e. ATC restrictions and poor weather). Critically, Flight Operations control must stay in constant contact with the Dispatcher, the Co-ordinator and the Flight Crew, to ensure that they are abreast of any operational changes.

In both airlines, Flight Operations Control is divided into a number of integrated functions which are managed by one high level function, the Duty Manager. Both airlines have functions dedicated to the management of crew problems (i.e. crew management), aircraft problems (i.e. aircraft management/maintenance) and problems with routing/ATC restrictions (i.e. real time dispatch). A late arriving flight might require an aircraft change and/or crew change (e.g. duty time limitations). Weather problems or ATC restrictions might require changes to routing. In Airline Two, ATC restrictions are an ongoing problem and route

changes are commonplace. Participants from Airline 5 stated that aircraft changes are typically actioned in approximately fifty percent of flights. Aircraft changes are made for several reasons. This includes (1) flight delays, (2) aircraft technical status issues and (3) commercial reasons (i.e. the flight had fewer passengers than expected and so a decision is taken to use a smaller aircraft). Crew management is a complex process for both airlines. If a flight is delayed, crews might exceed their duty time and as such are not legally able to fly the full duration of the next flight. Further, crew might get sick at short notice, necessitating replacement crew. Crew management must therefore recruit new crews and/or swap existing crews. In relation to Airline 2, the Crew Management representative remarked that *"this is often complicated by industrial agreements with Pilot and Cabin Crew unions"*. In both airlines, the Flight Operations Control representative observed that flight cancellations rarely occur.

FOC collaborate with the cockpit crew throughout the flight. Interviews reveal that there are certain fixed points in the process and/or specific types of situations that necessitate this collaboration. In relation the former, this includes (1) the pre-flight, dispatch of the flight, (2) approach and landing, and (3) taxi to gate. In terms of the latter, this includes (1) problems at the dispatch stage (i.e. weather issues, aircraft technical issues and ATC issues), (2) weather problems in cruise – potentially necessitating the crew to divert to an alternate, (3) weather problems during descent, approach and landing and (4) instances during approach and landing where ground operations information (i.e. runway in use and parking gate) is either unavailable and/or has not been communicated to the crew. As part of this, FOC use ACARS or VHF Radio. If the crew are on the ground, FOC either contact the Flight Crew directly using VHF Radio, or the Co-ordinator function relays information on their behalf to the crew.

Co-ordinator

Although the Co-ordinator is a Ground Operations function, the importance of this function was highlighted in interviews with personnel from both airlines. The Co-ordinator acts as a mediator between the crew and all other Flight Operations, Maintenance and Ground Operations functions, at the pre-flight stage. Typically the Co-ordinator provides the crew with operational updates information, once the crew have arrived at the aircraft. This includes updates concerning load requirements, fuel issues, aircraft technical issues and passenger issues.

Communication Methods & Tools

Participants reported that a range of both formal and informal communication methods are used by different flight planning personnel, to share information with other personnel, both within the Flight Planning process, and across other processes. For a summary of methods,

please see Table 13 below. Formal methods include committee meetings and the generation and review of reports. Informal methods include impromptu meetings, person to person communications and communications mediated by computing and/or radio tools.

Typically, the Dispatcher uses VHF radio and ACARS to communicate with Flight Crew. In addition, certain information is mediated by the Co-ordinator. Although not referred to in SOP's, participants noted that Flight Crew often use their mobile phone to contact the Dispatcher and/or Flight Operations Control.

Table 13: Flight Planning Communication Methods and Tools (Study 2)

Communication		Methods for Communication	Tools
From Flight Planning To Flight Crew	Aircraft Pairing & Rostering	Formal - Computer mediated	Send roster to crews and they review
	Dispatch	Formal - Person to person, Computer mediated Informal – person to person	Radio/Frequency ACARS
	Flight Operations Control	Formal - computer or radio mediated	Dispatch Computer Radio/Frequency ACARS Telephone in crew room Mobile phone
From Flight Crew to Flight Planning	Aircraft Pairing & Rostering	Formal – crew review roster and send feedback to Flight Planning	Email
	Dispatch	Formal - Person to person or computer mediated, or telephone mediated Informal - Person to person, use of mobile phone	Radio/Frequency ACARS Telephone in crew room Mobile Phone
	Flight Operations Control	Formal – computer, radio or telephone mediated Informal - use of mobile phone	Dispatch Computer Radio/Frequency ACARS Telephone in crew room Mobile Phone

Within Flight Planning		Formal: Internal committee meetings Informal: Impromptu meetings	Formal: (1) Reports and (2) Email summaries – reports of meetings Informal: (1) Email discussions
From Safety To Flight Planning	Aircraft Pairing & Rostering	Formal: Committee meetings and computer mediated	Formal: (1) Reports, (2) Email and (3) Alerts/Email
	Dispatch	Formal: Committee meetings and computer mediated	Formal: (1) Reports, (2) Email and (3) Alerts/Email
	Operations Control	Formal: Committee meetings and computer mediated	Formal: (1) Reports, (2) Email and (3) Alerts/Email

Process Design/Information Flow Problems & Improvement Recommendations

Information Flow from Flight Planning to Flight Crew

Participants from both airlines remarked that both the Dispatcher and the Co-ordinator do not always have the full information picture. Flight Operations Control communicates the latest operational information to them in a piecemeal fashion. Once obtained, both functions communicate what information they have to Flight Crew, with the caveat that further updates may be required. As a result, the relay of operational updates to Flight Crew is often piecemeal.

Dispatch participants from both airlines suggested that the information handover from Dispatch to Flight Crew could be improved. Dispatch might provide Flight Crew with enhanced information about (1) threats to be managed in flight, (2) fuel requirements (i.e. fuel trends information for specific routes/airports, composition of fuel figure and level of contingency fuel provided), (3) aircraft technical status information and (4) the latest weather information. A Dispatch representative from Airline 5 noted *"that given the requirements to produce multiple flight plans in the short term, it is not always possible to provide updated information shortly before the flight"*. In Airline 2, this function is handled by the short term/real time dispatch function within Flight Operations Control. Given both environmental issues and the peculiarities of the local ATC situation, the flight plan is often updated several times before the flight. In this instance, external process constraints (i.e. ATC process) impact on both the flight planning function and on Flight Crew.

In both airlines, it was noted that Flight Crew communication with Flight Operations Control/Duty Manager is regularly mediated via the Co-ordinator. However, if a major issue arises, the Duty Manager agrees a course of action directly with the Captain. In both airlines,

it was suggested that communication between Flight Operations Control and Flight Crew might be improved. Two participants suggested that this might be facilitated by the use of a real time decision making tool. Potentially, Flight Operations Control would use such a tool to manage the operation, and this would automatically send Flight Crew the latest information regarding operational changes and/or flight plan updates.

Information Flow within Flight Planning

A Dispatch participant from Airline 5 remarked that they usually report on operational problems verbally in both weekly and monthly flight planning meetings. Similarly, representatives from the airline's Flight Operations Management department observed that problems are discussed at the team's weekly meetings. If required, feedback is provided to the relevant Flight Planning function, although this is not always formalised. A Flight Operations Management participant from Airline 2 stated *"We are constantly tackling the same problems"*. Further, this participant went on to say that the airline *"does not always learn from past problems"*. It was suggested that these problems might be ameliorated by improved co-ordination/communication between Flight Planning, Dispatch and Flight Operations Control.

Information Flow from Safety to Flight Planning

Flight Planning, Dispatch and Flight Operations Control participants from both airlines remarked that they require better feedback from their airline's Safety department regarding crew problems that are relevant to flight planning (i.e. problems with routes/airports, local weather issues that present a flight threat, crew composition issues and so forth). It was suggested that the outcome of safety/risk assessments might be communicated to different Flight Planning functions, so that known safety issues and/or potential flight risks, might be factored into the design of future flight plans. In addition, real time feedback about safety issues pertaining to current flights might be communicated to Dispatch and Flight Operations Control personnel. This information might also be relayed to Flight Crew. One participant from Airline 5 noted that *"currently this information is not being utilized to its maximum potential and/or being communicated to the right personnel"*.

Information Flow from Flight Planning to Safety

In both airlines, participants stated that both the Flight Planning system used by Dispatch and the Operations Management system used by Flight Operations Control features relevant information about the ongoing management of the operation and associated risks, relevant to Safety/Risk personnel. Potentially, this information might be communicated to relevant Safety/Risk personnel to support their safety/risk management iniatives.

Latest Initiatives

Overall, participants from both airlines emphasized that improved information sharing would facilitate enhanced team work across Flight Planning, Dispatch, the Co-ordinator, Flight Operations Control and Flight Crew. In this respect, participants from Airline 2 pointed to a new process and technology currently being specified by the airline, which will gather and integrate all relevant safety and operational information, so that it can be utilized in the Flight Planning process. It was noted that this project is currently being led by the airline's Flight Planning Department.

In relation to safety information, this technology will gather all relevant mandatory and voluntary safety reports. Further, it will gather the outputs of all relevant safety analyses undertaken by the airline's safety department. In terms of operational information, this will gather and integrate information from Flight Crew (i.e. Voyage reports/Journey Logs and Delay reports), and from Flight Operations Control (i.e. information pertaining to the management of delays, aircraft technical issues and crew changes). Currently, the Flight Planning department is specifying the different levels of reports required, and how these will be used by the different Flight Planning functions. One of the Dispatch participants noted that at this time, this new process and technology *"is still an aspiration and much work is still required"*. Further, it was noted that *"this will require a lot of collaboration with the Safety Department"*.

5. DISCUSSION

Flight Planning Process

The functional logic of the flight planning process follows from the temporal and dynamic nature of the flight operation. Accordingly, the Flight Plan is progressively defined. Much of the Flight Plan is subject to change. Thus, the Flight Plan is not finalized until shortly before the dispatch of the flight and/or at the dispatch stage.

In terms of the thesis problem, information pertaining to the aircraft pairing and rostering process, and the dispatch process is of most interest. In this regard, this research illuminates the nature of these processes, and how they impinge on Flight Crew. As noted in the introduction, existing process descriptions are sparse. Further, particular process and task dependencies are not addressed.

The application of CRM principles to aircraft pairing and rostering practices is not reported in the literature. However, this research tells a different story. CRM concepts are embedded in this activity. In both airlines, aircraft pairing and rostering activities endeavour to optimise crew composition. This follows from reports feedback provided by Safety to Flight Planning.

This underscores the importance of (1) the provision of feedback from Safety to Flight Planning, and (2) the intelligent use of this information, in the Flight Planning process.

This research illuminates several dependencies between the task activities of different Flight Planning functions, and Flight Crew. Aircraft pairing and rostering activities in relation to ensuring quality crew pairings, impact on Flight Crew team concepts. The work of the Dispatcher before the dispatch of the flight, in terms of managing flight threats, has an implication for the risk level/complexity of the flight, faced by Flight Crew. The quality of the Flight Plan produced by Dispatch, has an impact on Flight Crew situation awareness and the quality of the pre-flight, flight planning and briefing task. Moreover, the task activities of the Dispatcher, in terms of collaboration with Flight Crew at the pre-flight stage, impact on the design of the Flight Plan, and crew management of flight threats. Lastly, the quality of collaboration between Flight Operations Control and Flight Crew, impacts on the management of flight threats. Further, this collaboration has an impact on the signoff of the Flight Plan.

This research points to the important role of Dispatch and Flight Operations Control, in terms of managing flight plan issues/threats, shortly before the flight commences. Currently, Flight Operations manuals tend to report on this interaction, in relation to Flight Crew/Dispatch co-ordination. The role of Flight Operations Control is underspecified. Further, the ongoing communication between Flight Operations Control and Flight Crew during flight in relation to the management of operation and environmental issues is not addressed. Thus, this research highlights the level of support provided by these functions to Flight Crew. This in turn, supports a team based conception of Flight Crew task performance. This has implications for existing models of Flight Crew task performance. This is discussed in more detail below.

This research suggests potential weaknesses in relation to the provision of safety feedback from Safety/Risk functions to aircraft pairing and rostering, and to Dispatchers. This mostly reflects the assertions of a small number of Flight Planning personnel in these interviews. It should be noted that these interviews did not investigate the specific evidence for this in much detail. Overall, a more detailed assessment of the quality of this information flow and specific information flow problems is required. Further, Flight Planning feedback might be validated with airline Safety/Risk functions. Nonetheless, Flight Planning requests for improved feedback mechanisms would accord with the principles of a quality SMS as defined by ICAO (2006, 2009). Following from this, we might argue that new processes and technology are required to address these issues, albeit these warrant more detailed extrapolation. Critically, it is necessary to formalize and specify the contributions of safety to Production Management (i.e. aircraft pairing and rostering process), and to Dispatch (i.e. production of the Flight Plan). Further, it is necessary to define how these will be used in the Flight Planning process. What process design changes will be required both at an

operational (i.e. Flight Planning and Active Flight Operation) and organisational level (i.e. Safety/Quality/Improvement process), to facilitate a more intelligent Flight Planning process?

Further, this research suggests that the process of sharing information between Safety, Dispatch and Flight Operations Control at the dispatch stage requires attention. Also, the process for sharing information between Safety, Flight Operations Control and Flight Crew in real time warrants investigation. Again, detailed feedback about existing process/information sharing problems was not obtained, and the specific issues need to be explored in more detail. Nonetheless, given the identification of task dependencies between these functions and Flight Crew as identified earlier, we might argue that such improvements are in principle welcome. That is, the introduction of new technology to assist and/or improve information flow between these different functions at this time should enhance Flight Crew task performance.

Pre-flight, Flight Planning and Briefing Task

This research highlights certain core characteristics of the pre-flight, flight planning and briefing task. As shown, this task is (1) shaped by the underlying design of the Flight Operations processes that link to it, (2) context dependent and (3) collaborative. It also indicates that the design of the Dispatch process shapes the Flight Crew task. The design of this process however varies depending on the flight type, and complexity/risk level of the flight. This in turn has an impact on the nature and level of co-ordination between Flight Crew and Dispatch, at the pre-flight stage. Further, the complexity/risk level of the flight has a bearing on the quality and depth of the briefing undertaken by the crew. There is considerable collaboration between Flight Planning functions and Flight Crew at the pre-flight stage. As shown, all emerging issues are managed by Dispatch and Flight Operations Control either shortly before crew arrive, and/or while the crew are dispatching the flight. If an issue arises while a flight is being dispatched, the Dispatcher will interrupt the briefing, and relay all relevant information to the crew. In support of the research of Bannon (1991), in relation to the use of technology to support collaborative/group work, potentially, such interruptions might be better managed by the introduction of new technologies supporting enhanced communication/collaboration practices.

Implications: Requirements for a New Briefing Tool

This research has several implications in terms of the introduction of an electronic flight planning and briefing tool. Given that flights are characterized by different levels of risk, an improved tool might feature information about the risk status of the flight. This is not a straightforward task. Specifically, it requires the specification of relevant underlying safety management processes, to support the population of actual risk information. Potentially

some of the flight plan information available to Dispatchers might be relayed to Flight Crew, via an improved electronic Flight Plan. The scope of this would need to be specified (i.e. level of fuel information and aircraft technical status information). Currently, information sharing between Flight Operations Control, Dispatch and Flight Crew is partially supported by existing tools (i.e. VHF Radio and ACARS). Interviews with personnel from Airline 5 point to a possible solution. An improved tool might automate the communication of updates information to Flight Crew. This would ensure that Dispatch/FOC had more time to perform their core problem solving tasks. Further, as highlighted by participants from Airline 5, this tool might feature certain higher level decision support functionality, to facilitate remote decision support/collaboration between Flight Crew and these agents. This requires further research.

6. CONCLUSIONS

This study yields a high level picture of the Flight Planning process and the relationship between this process and Flight Crew task activities.

Flight Crew collaboration with both the Dispatch and Flight Operations Control function varies according to the complexity of the flight. The quality of Flight Crew collaboration with these functions both at the pre-flight stage and throughout the flight has a bearing on the quality of Flight Crew task performance and the broader safety outcome of the flight.

In specifying the Flight Plan, the Dispatcher aggregates information from all relevant parties (e.g. ATC, Maintenance, Ground Control and so forth). Much of this information is directly accessible from the Flight Planning system. Potentially certain information available to Dispatch and Flight Operations Control/Duty Manager might also be relayed to Flight Crew, via an improved electronic flight plan.

The communication of safety/risk information from the Safety Department to relevant personnel involved in the Flight Planning process (i.e. Flight Planning, Dispatch and Flight Operations Control) might be improved. Potentially, feedback from different safety/risk analyses might be communicated to Flight Planning personnel, to support improved Flight Planning activities. As such, potential flight risks might be resolved in advance of the flight. Certain threats may not be resolved. Information about flight specific risks/threats (i.e. not mitigated in the Flight Planning process) might therefore be included in an improved electronic Flight Plan, to assist Flight Crew CRM and TEM activities.

Certain caveats should be noted. This research presents the perspective of Flight Planning personnel in relation to existing process problems, and particular process and task dependencies between Flight Planning and Flight Crew. The emerging process accounts are quite high level. Process and task relationships were not explored in huge detail. Specific

process problems related to the communication of information from Safety to Flight Planning personnel require more comprehensive investigation. In this way, the evidence presented in this study in relation to process design improvements is quite high level. Nonetheless, the evidence follows the spirit of SMS guidelines as defined by ICAO (2006, 2009).

Study 3: Performance/Safety Management, Procedures Design and Crew Resource Management Training

1. CHAPTER INTRODUCTION

This study examines the broader safety management process of which both airline performance management and CRM training activities form a part. Specifically, this study follows up on certain of the issues raised in Study 1, concerning the (1) the application of procedures in operations, (2) the nature of the pre-flight flight planning and briefing task, (3) the design of existing airline safety management processes and tools (and in particular, the design of safety feedback processes), and (4) CRM training. Overall, this has implications for the advancement of a model of Flight Crew task activity (both generally and in relation to the pre-flight, flight planning and briefing task), and the specification of the requirements for an improved tool assisting Flight Crew planning and briefing activities at the pre-flight stage.

Three related sub studies were undertaken. Study 3:1 examines airline performance/safety management processes and tools. In particular, it focuses on the opportunity to improve existing feedback processes, to enable the provision of improved safety/risk feedback to Flight Crew, at the pre-flight, flight planning and briefing phase. This study was conducted with Airlines 2, 3 and 5. Study 3:2 follows up on certain issues which emerged in the process workshop with Airline 2, in relation to the Alta approach and the airlines experiences with the LOSA methodology. As part of this, it focuses on issues pertaining to (1) the use of procedures in operations, (2) the role of the pre-flight, flight planning and briefing task, and (3) the requirement to extend existing performance management methods to take into account appropriate deviations in procedures. Study 3:3 reports on additional research undertaken with Airline 5 in relation to the airline's CRM training programme. Further, it reports on recent airline developments pertaining to the introduction of new Flight Crew briefing and reporting tools, predicated on CRM training concepts. These tools have implications for the design of a new tool assisting Flight Crew performance of the pre-flight, flight planning and briefing task.

Before reporting on the findings of the individual studies, the theoretical context for these studies is first reviewed. This includes a review of the literature pertaining to human performance/error theories and performance shaping factors (PSFs). Further, airline directives in relation to managing safety are also examined. This includes an introduction to airline safety management systems and a review of a subset of airline safety management

practices. In terms of the latter, this includes standard operating procedures, CRM training approaches and the LOSA evaluation methodology.

2. INTRODUCTION

Error Frameworks

Error frameworks provide an explanation why incidents and/or accidents occur. Individualistic explanations' focus on specific crew factors which contribute to accidents. In Endsley's view, loss of situation awareness, or reduced situation awareness is a significant contributing factor in Flight Crew error (1999b). Inattention or decreased vigilance as cited in air safety reports has been a contributor to operational errors, incidents and accidents. Decreased vigilance manifests itself in several ways. These are referred to as *'hazardous state of awareness'* (FAA, 1996). Poor crew resource management has also been cited as a key contributory factor in a large number of accidents. Other explanations focus on problems related to crew task management issues (Chou, C.D., Madhavan, D., and Funk, K., 1996, Wilson, J, R and Funk, K., 1998, Funk, 1999).

Systemic explanations concentrate on the different organizational factors which contribute to incidents and/or accidents. According to Dekker (2002), human error is a symptom of trouble deeper inside a system. In explaining this, Dekker distinguishes the (1) sharp end – people in direct contact with the safety critical process and (2) the blunt end – the organisation or set of organisations that supports, drives, and shapes activities at the sharp end. Reason addresses the errors committed by operators as well as the preconditions and organizational factors that contributed to such errors (1990, 1995). Similar to Dekker, Reason (1990, 1995) argues that accidents have multiple causes involving many different people spanning different levels of the organisation and beyond.

Man-Made Disasters theory (Turner, 1978; Turner and Pidgeon, 1997) focuses on information failures, specifically the link between accidents, poor management and the mishandling of warning signals. Central to this theory is the idea that disasters arise from lack of foresight and weak information/knowledge in terms of the people involved. Turner argues that disaster-prone organisations are characterized by people working with incomplete information, poor communication or complacent work practices. In such organisations, warning signs indicating the possible development of a hazardous situation is missed, misunderstood, miscommunicated or minimised (1978). In similar terms, Weick and Roberts (1993) argue that the tendency of people to make do with the information they have to hand, and to simplify interpretations creates collective blind spots which can hinder the recognition of emerging problems. Nonetheless, some organisations are more expert at avoiding accidents. Weick (1999) defines a *"high reliability organization"* as one in which the

culture of an organization contributes to its ability to be safe and reliable. This is achieved through what Weick and Roberts (1993) term the *"collective mind,"* where distributed information processing receives proactive attention and heedful interrelating to form an ongoing accurate representation of an unfolding situation.

Other theories focus on the organisations safety culture. As emphasized by Merritt and Helmreich (1996), a safety culture results from a variety of organisational efforts. According to the authors, norms of compliance with SOPs, resources available for training and maintenance, and relations between management and Flight Crew all influence crew behaviours and hence, the probability of safe flight (Merritt and Helmreich, 1996).

Performance Shaping Factors

The concept of performance shaping factors (PSF) was first introduced by Swain (1967). Swain conceived of PSF as *"the regulation item for the introduction of the error rate"* or *"the providing items for the prediction of human error"*. Miller and Swain define PSFs as the factors that contribute to accidents and/or influence human error rates (1987).

According to Miller and Swain, the local actions of the flight crew are affected by a variety of immediate influences or performance shaping factors (1987). Miller and Swain (1987) distinguish factors which are primarily external to the individual and factors which are primarily internal. External factors include environmental conditions, equipment design, operating manuals and procedures and poor supervision. Internal PSFs include emotional state, physical condition, stress level, experience, and task knowledge.

As stated by O Hare (2006), PSFs are considered to substantially increase the likelihood of human error. Nonetheless, poor PSF conditions do not always result in unsafe acts or incidents. The quality of working conditions often varies. In this respect, all work involves the management of different challenges/levels of complexity. As stated by Johnston (2003), Pilots draw upon their own expertise and judgement, in managing different levels of complexity. Further, Pilots draw upon specific CRM behaviours as outlined previously, to identify and manage the impact of adverse PSF conditions.

PSFs have been incorporated in human reliability analyses. This includes techniques for human error rate prediction such as THERP (Swain & Guttman, 1983). PSFs also feature in the analysis of accident information. For example, the human factors analysis and classification system (HFACS) approach (Wiegmann & Shappell, 2003).

Introduction to Flight Safety

The International Civil Aviation Organisation (ICAO) is charged with the safe and orderly growth of international civil aviation throughout the world. Each country has its own national

authority, which regulates airlines and aviation practice at a national level. Within Europe the national authorities follow European Union directives. In the USA, the Federal Aviation Authority (FAA) is responsible for aviation regulation. Since 2003, a European wide regulation and certification process run by the European Aviation Safety Agency (EASA) has been set up to identify, implement and evaluate regulations for flight operations and aircraft design (including Flight Deck design).

Flight Operations regulation consists of regulation in relation to crew management and the development and management of the airlines safety management system (SMS). In relation to Flight Operations, regulation exists for crew qualification, crew licensing, crew training (both new and recurrent training) and duty times. Further, specific regulation governs airline safety audits, including Flight Crew line checks and back office audits.

Airline Safety Management Systems

The International Civil Aviation Organisation provides a definition of safety in relation to risk management (2006). Safety is defined as the state in which the risk to person's or property damage is reduced and maintained at or below, an acceptable level through a continuing process of identification and risk management (ICAO, 2006). In this definition, safety does not mean risk free. Rather, it means that risks are managed, thereby ensuring that they remain at an acceptable level.

As noted in Study 1, a safety management system is defined as 'an organized approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures' (ICAO, 2006). Further, ICAO define a safety program in relation to 'the regulations and directives for the conduct of safe operations in aviation from the perspective of aircraft operators and those providing air traffic services, aerodromes and aircraft maintenance' (2006). All such parties are required to develop a safety programme in accordance with ICAO criteria.

ICAO mandates the development of proactive safety management systems. This is characterized by the following elements:

- Application of scientifically-based, risk management methods
- Senior management's commitment to the management of safety
- A corporate safety culture that fosters safe practices, encourages safety communications and actively manages safety with the same attention to results as financial management
- Effective implementation of Standard Operating Procedures (SOPs), including the use of checklists and briefings
- A non-punitive environment to foster effective incident and hazard reporting

- Systems to collect, analyze, and share safety-related data arising from normal operations
- Competent investigation of accidents and serious incidents, identifying systemic safety deficiencies
- Integration of safety training (including Human Factors) for operational personnel
- Sharing safety lessons learned and best practices through the active exchange of safety information
- Systematic safety oversight aimed at assessing safety performance and reducing or eliminating any emerging problem areas.

Procedures

The development and management of standard operating procedures (SOPs) is central to safety management. From a Flight Crew perspective, procedures define specific role task requirements for different flight phases. These are documented in airline procedures manuals and in specific checklists used at different flight phases. Role/task requirements are also defined for other operational and management roles. However, as noted in Study 1, performance does not always follow procedures. Pilots are often required to adapt procedures in terms of their specific situation, to ensure that the aircraft lands safely. What therefore is the role of procedures in flight operations?

Line Operations Safety Audit (LOSA)

The Line Operations Safety Audit (LOSA) is an example of an observer based reporting methodology. In the LOSA framework, performance is evaluated in terms of conformance to technical and CRM procedures. Trained observers ride jump-seat in the cockpit, providing feedback about Flight Crew technical and non technical performance.

The TEM framework forms the theoretical basis for the LOSA methodology. Following from the TEM framework, five types of crew errors are classified. This includes: intentional non compliance, procedural, communication, proficiency and operational decision. Observers document external threats and record Flight Crew errors in terms of their type, management response and the outcome (i.e. aircraft states). Further, observers rate crew members on a range of CRM behavioural markers (Helmreich et al, 2001). The LOSA methodology defines several 'behavioural markers'. This includes: SOP briefing, plans stated, workload assignment, contingency management, monitor/crosscheck, workload management, vigilance, automation management, evaluation of plans, inquiry, assertiveness, communication environment and leadership.

Arguably, the LOSA methodology cannot account for appropriate deviations in procedures. In the LOSA framework, such deviations are interpreted as degraded performance (i.e. error of not following procedures). As stated earlier, flight situations can be complex. Periodically, Pilots are required to optimise procedures to ensure a safe outcome. From this perspective, it seems that a valid methodology should account for appropriate deviations from procedures (i.e. deviations that stabilize the operational process as opposed to destabilize it). Moreover, as noted in Study 1, Flight Crew task performance is collaborative. Thus, to evaluate Flight Crew task activity, we need to consider the task activity of all relevant operators that collaborate with Flight Crew. In this regard, the LOSA methodology fails to provide a complete performance picture.

Crew Resource Management (CRM) Training

CRM is originally an aviation concept. During the 1970s, post accident investigation identified poor communication and information sharing practices and discrepancies in the division of duties between crew members, as a causative factor in aviation accidents (Stone & Babcock, 1988). This led American Airlines in conjunction with NASA to develop the first Crew Resource Management (CRM) program to combat these factors.

The objective of CRM training is to improve crew performance in the areas of decision making, threat and error management, communication, leadership/managerial skills, stress, fatigue management and teamwork (Jensen, 1995). The secondary objective of CRM programs is to improve crew morale and the efficiency of operations (Helmreich, R.L., & Merritt, A.C.). Commercial pilots and cabin crew attend CRM courses as part of their recurrent training at least once and usually twice a year. As noted by Helmreich and Merritt, CRM is not a one-time intervention, but rather a critical and continuing component of a safety culture (2000). Current regulatory requirements (Joint Aviation Authority, 1998) in relation to training requirements include the following topics:

- Human error and reliability, error chain, error prevention and detection
- Company safety culture, SOPs and organisational factors
- Stress, stress management, fatigue and vigilance
- Information acquisition and processing, situation awareness and workload management;
- Decision making
- Communication and co-ordination inside and outside the cockpit
- Leadership, team behaviour and synergy.

Typically CRM training involves classroom instruction. Training focuses on the application and practices of non technical skills/knowledge in operational settings (Johnston, 1993).

CRM programmes usually deploy real world case studies, or data reflecting current airline operational issues. The crew are led through the process of learning how to question and validate information, how to identify threats, how to brief and debrief crew members, and how to work together as a team. Further, CRM training provides instruction in threat and error management (TEM) activities.

To date, CRM concepts have only been harnessed as part of specific training activities. Potentially, CRM concepts might be exploited in terms of the design of improved Flight Crew tools supporting both operational and safety practice. In particular, these concepts might be utilized in terms of the introduction of an improved electronic pre-flight, flight planning and briefing tool.

3. STUDY 3:1 - PERFORMANCE AND SAFETY MANAGEMENT PROCESSES AND TOOLS

Research Design

Background

The first study highlighted several problems pertaining to the design of existing performance monitoring processes and tools. These findings mostly reflect a Flight Crew perspective on these processes and tools. Specifically, Flight Crew participants reported problems with regard to the design of current reporting tools. Flight Crew participants also stated that they regularly fail to receive feedback about the status of prior reports filed and associated safety actions. A lack of transparency with regard to the nature of the broader safety management process which underlies the design of existing performance management processes and tools was also reported. This wider SMS process was not mapped in Study 1. As such, it was decided to investigate the nature of the broader SMS process. Further, it was decided to explore potential process redesign improvement opportunities concerning the provision of feedback from Safety to Flight Crew, by means of a new electronic briefing tool.

Objectives

The objectives of this study include:

- To understand existing airline performance/safety management processes and tools
- To elicit information about the airlines experience with existing performance/safety management tools
- To identify how existing performance/safety management tools might be improved – both generally, and in relation to the development of tools supporting Flight Crew performance of the pre-flight, flight planning and briefing task.

Method

Eight one to one interviews were conducted with relevant airline personnel. This involved the participation of two participants from Airline 2, three participants from Airline 3, and three participants from Airline 5. Interviews were conducted at the airline's offices. Both the researcher and the HILAS airline representative attended the interviews. In all cases, the HILAS representative was a Pilot and had attended the process workshops.

Before the interview commenced, the researcher explained the interview purpose and reminded participants about the confidentiality of interview findings. The researcher then explained the nature and objectives of the HILAS project. Participants were then asked a series of open questions concerning the performance evaluation methods used by the airline, the process for this, and issues relating to the use of these tools. Following this, there was a free form discussion as to how future HILAS tools might function to facilitate their work, specifically in relation to improving process design/information flow.

Participant names, role and specific interview feedback were recorded using paper and pen. After the session, all transcripts were de-identified (i.e. participant name but not role). Overall, the data was analysed in relation to several core themes. This includes (1) a description of existing performance/safety management processes, (2) problems with existing processes and tools and (3) latest developments, as reported below. On completion of this, specific HILAS reports were written. These reports were reviewed by airline representatives and feedback was provided.

Prior to the development of scenarios and prototypes for the new electronic briefing tool, these research findings were co-related with the other findings of Study 3 (i.e. Study 3:2 & Study 3:3), the findings of the processing mapping study (i.e. Study 1), the Flight Planning Study (i.e. Study 2), and the Flight Crew task analysis study (i.e Study 4).

Participants

This study involved eight participants. Table 14 below provides a breakdown of participants.

Table 14: Breakdown of Participants (Study 3:1)

Method	Airline Ref	Participant Number	Role/Function
Interviews	Airline 2	1	Head of Procedures
	Airline 2	2	FDM Analyst
	Airline 3	3	Director of Safety
	Airline 3	4	FDM Analyst
	Airline 3	5	Safety Analyst
	Airline 5	6	Flight Safety Director
	Airline 5	7	FDM Analyst
	Airline 5	8	Safety Analyst

Results

High Level Performance/Safety Management Process

High Level Process

In principle, the performance/safety management process involves several sequential steps, following ICAO guidance. First both reports data and flight data are gathered from diverse sources. This information is then integrated and analysed. Currently, this is a manual process. Depending on the timeframe, this analysis is either performed by the Safety personnel alone, or with the help of other relevant functions. Solutions are then identified. An implementation plan is drafted and the solution is implemented. This solution is monitored, to ensure the problem has been successfully solved. Lastly, relevant findings are communicated to key operational and organisational functions, to assist ongoing operations management.

As reported by participants across the interviews, this process is not always strictly followed. As stated by one participant: *"this is an ideal process"*. The specific nature of the above processes (i.e. depth of analysis, scope of people involved in relation to the identification of corrective actions and timeframe) varies according to the complexity of the problem. Typically the analysis of complex problems follows this process. However, as reported by a Safety Officer from Airline 5, *"If the problem is simple, certain steps might be skipped"*.

Reactive and Proactive Approaches

Within this overall process, two specific performance/safety management approaches were distinguished. This includes (1) reactive and (2) proactive approaches.

In terms of reactive approaches, this concerns the evaluation of information relating to prior safety critical events and/or incidents/accidents, to understand why they occurred (i.e. contributory factors and underlying root causes). Following this analysis, necessary corrective actions are taken, to ensure that the event does not recur. This might involve making changes to the existing process design, updating specific SOPs and providing feedback to crew about particular technical procedures in training sessions. Proactive approaches involve gathering and analysing data about routine performance along with prior safety critical events and/or incidents/accidents to make predictions about potential operational and safety risks. Critically, these potential threats/risks need to be managed, before an event occurs. As stated by the Director of Safety from Airline 3: *"corrective actions are taken ahead of time"*.

It was stated that the procedures for undertaking a 'reactive' evaluation are long established and clearly defined. Alternatively, proactive approaches are currently being defined and in many cases, more an aspiration than a reality. Nonetheless, all of the airlines appear to be moving towards a more proactive approach to safety management. Specific findings related to this are presented in a later section.

Tactical and Strategic Approaches

As noted earlier, participants remarked that the timeframe for identifying and resolving performance/safety problems often varies. In this regard, participants distinguished between (1) tactical performance/safety/risk management (i.e. short-term) and (2) strategic performance/safety/risk management (i.e. long term).

Tactical approaches are implemented over a shorter time period than strategic approaches. For example, this might be the analysis of feedback pertaining to a bird strike, or a problem at a simple problem which emerged at a particular airport (i.e. lack of steps and/or delays obtaining information from the Co-ordinator). In the case of tactical approaches, key information is gathered and integrated with other relevant information. The overall information picture is analysed by a small group of people, in a relatively short time period. Following this, necessary corrective actions are identified and taken. Often this involves consultation with personnel from one particular department.

Strategic analyses typically involve the analysis of more complex problems, such as Flight Crew CRM issues. In terms of the activities outlined above, these occur over a longer period. Further, data gathering, integration and analysis activities are more detailed. Often a number of departments are involved in the analysis of performance issues/risks, and the

identification of corrective actions. In both cases, corrective actions are monitored to ensure the desired outcome. If this is not obtained, additional analysis/problem solving is undertaken.

Process Problems & Requirements for Improved Processes

Across the airlines, participants noted that the ICAO guidelines in relation to the specification of an airline SMS provide 'in principle' guidance. As stated by a Safety Officer from Airline 5: *"These guidelines do not specifically state how the SMS process should be implemented practically"*. As such, the airline is required to specify the particular methods and steps. Historically, each airline has had a team dedicated to defining and improving the particular performance/safety management process and assessing issues with regard to regulatory compliance. With the introduction of the new SMS requirements, the activities of these groups have been redirected to focus on the specification of the airline's SMS. Currently, each airline has a team working on this. In all cases, participants reported that although the new airline's SMS follows the principles of the ICAO guidelines, the existing process design requires further specification and improvement. As reported by a Safety Officer from Airline Five, *"there is a gap between the existing process and the aspirations of ICAO"*.

All of the airlines have clear processes for gathering data. That said, across the airlines, participants noted that specific reporting formats might be improved. Currently, the processes for integrating data are manual and poorly defined. Typically, the process for comparing flight technical data and voluntary reports data is a manual process. Here, participants from Airline 2 and 3, referred to problems reconciling the 'what' and the 'why'. Airline 2 has advanced a solution for this. This is reported in a subsequent section.

Each airline has devised methods for analysing the collective data picture. Participants from Airline 2 and 3 noted that these specific methods are under review – especially in relation to the definition of new proactive risk assessment approaches.

Typically, feedback to flight planning functions (e.g. Aircraft Pairing and Roster, Dispatch, Flight Operations Management), takes the form of oral presentations in committee meetings, formal written reports and emails. One participant from Airline Five characterized these processes as *"poorly defined and often ad hoc"*. Participants noted that the relay of feedback to relevant personnel might be improved. As noted by all personnel, in an ideal world, existing problems and/or potential future problems might be flagged to relevant roles (i.e. Flight Planning, Dispatch, Flight Operations Control and Flight Crew) immediately, so that in the short term, these can be avoided. In parallel, longer term solutions would need to be identified and implemented. Communications might also be provided to relevant personnel in relation to what the problems are, and how these are being ameliorated.

Across the airlines, it was noted that feedback to Flight Crew might be improved. Currently, the crew obtain safety feedback through communications in monthly airline safety magazines

and in training sessions. Flight Crew do not receive information about flight specific threats/risks.

Problems with Existing Tools & Requirements for Improved Tools

Pilots are required to complete a range of both operational (i.e. Journey Log) and human factors/safety reports (i.e. ASR and MOR) at the end of the flight. Critically, feedback about routine operations is not captured in these reports.

Currently, there is a low uptake in terms of voluntary reports. Further, near misses are not always reported. Across the airlines, participants attributed this to the design of existing reporting tools. All participants indicated that existing forms should be available in electronic format. Further, the design of new tools might take into account known reporting barriers (i.e. time available to report and access to reporting forms). Also, it was observed that the Flight Crew EFB might provide reporting functionality. In addition, electronic forms might be accessible on the staff intranet accessible from the office or home, so that crews could submit feedback and/or improvement recommendations, at their own convenience.

Participants noted that existing tools have a number of positive features and these should be retained. Specifically, this relates to the provision of non jeopardy feedback mechanisms, associated with the LOSA methodology.

Existing performance management/safety management tools fail to provide a real time picture of routine operations supporting predictive risk management. The Director of Safety at Airline 3 stated that *"Current tools fail to address issues relating to risk prediction and mitigation"*. From his perspective existing tools (i.e. LOSA, FDM and ASR) *"cannot be used to predict safety threats and/or prevent incidents/accidents occurring"*.

It was observed that existing tools fail to capture overall system performance information. Mostly, the reports information gathered reflects the Flight Crew perspective on an event. Although other roles are required to complete reports, (i.e. Ground Operations, Maintenance, Cabin Crew and ATC), this information is not always linked to Flight Crew information. Further, aircraft technical information is gathered and processed separately.

As shown, airlines typically gather data using a range of different tools. The use of many discrete tools presents certain information management challenges. Much valuable information is gathered about the operation. Yet this information is gathered, analyzed and stored in different formats. As such, it is difficult to obtain an overall integrated safety/risk picture. Currently, there is limited technical and organisational capability, in terms of integrating and analysing performance/safety data, so that a system picture is obtained, and correction actions identified. Participants remarked that this necessitates gathering, integrating and analysing both performance data and background information across a range of airline sources. This includes: human performance information (i.e. reports from all

relevant actors involved in the flight operations process and not just Flight Crew}, aircraft technical data, flight plan data, weather data, roster data, training information and safety information. Further, participants from Airline 2, 3 and 5 observed that the ensuing analysis needs to be communicated to different airline organisation/functions, in appropriate formats.

All participants noted that FDM data does not provide information about why an event occurred. Further participants observed that human factors data (i.e. captured in mandatory occurrence reports, air safety reports and optional human factors reports) is not linked to aircraft technical data. All participants stated that it would be useful to integrate aircraft technical data and human factors data. In this respect, crew would be required to complete specific human factors reports, if particular flight parameters are exceeded. It was suggested that this might be implemented on a class two or three EFB, which would be linked to the FDM system on board the aircraft. Across the airlines, participants emphasized the sensitive nature of FDM data. In this respect, participants highlighted union agreements regarding the use of FDM data. It was noted that changes to the use of this data would necessitate negotiation and agreement with airline unions.

Latest Developments: Processes and Tools

Currently, all three airlines are introducing (or are in the process of introducing) enhanced performance management tools, in accordance with regulatory guidance (ICAO, 2006, 2009). Central to these iniatives is the development of new risk management and information sharing tools and practices, complementing existing performance management systems. The overall objective of such systems is to collect real time data on a routine basis, so that the safety levels of the operation can be assessed, future risks predicted, necessary corrective changes undertaken, and feedback provided to relevant personnel. Further, many airlines are focusing on enhancing knowledge integration both internally (i.e. within airline) and externally (i.e. with authorities and other airlines).

Airline 2 is currently developing a risk management system as part of the airline's overall SMS development. In the past, this airline followed a reactive safety model. In 2000/2001, this airline developed a reactive risk management tool, to meet regulatory requirements regarding organizational structures and the establishment of an Accident Prevention and Flight Safety Program. This tool allows safety analysts to categorize risks and allocate responsibility to specific roles or departments. This in turn facilitates the systematic production of countermeasures and follow-up activities. According to the airline's Head of Procedures/Management Pilot, *"a more proactive safety management strategy is now required"*. In his view, *"this requires integration of safety data from different perspectives in real time, or close to real time"*.

Further, Airlines 3 and 5 are in the process of introducing new risk management concepts/methods in relation to crew composition. At Airline 3, this primarily concerns risk

assessment in relation to crew fatigue. In the case of Airline 5, new risk assessment procedures are being introduced in relation to crew composition. As part of this, the airline is currently developing crew profiles for each crew member. This includes crew rank, overall flight experience, training background (i.e. military or civil) and details, licence information, number of flights flown in different aircraft type, route familiarity, age and gender. This airline plans to use this information at the flight planning stage, to *"ensure that any potential crew composition risks are identified and managed"*.

Further, new tools are being developed in Airline 5 to facilitate information sharing in relation to flight threats/risks and broader safety issues throughout the organisation. This includes information sharing between different departments involved in similar and different processes. As part of this, decision support tools are being developed for use by Flight Operations Control, to support real-time decision making in relation to flight threats. Potentially, these tools might also be used to share information between Flight Crew and Flight Operations Control.

Airlines 2 and 3 have devised their own methodologies for linking the data captured in human factors reports with aircraft technical data. Currently, this is a manual process. First, FDM data is captured and analysed. If a safety exception is recorded, the analyst either looks for an air safety report or a human factors report. If this is not available, the analyst will request one. Both the access and use of this data (i.e. requesting reports) is based on strict agreements between the airline and the respective Pilot union.

All three airlines already have, or are in the process of implementing, voluntary/optional reporting systems, to obtain routine feedback about process problems and improvement suggestions. Critically, these systems are confidential, to mitigate crew concerns regarding potential punitive outcomes. Further, airlines are also focusing on improving information flow between the cockpit and other operational roles and related ground systems.

4. STUDY 3:2 - ALTA SCENARIO

Research Design

Background

During the process workshop with Airline 2, the Head of Procedures referred to the *"complexity of flying certain approaches in Northern Norway"*. It was noted that Pilots receive special training for such approaches. Further, Pilots flying such approaches perform a special briefing in advance of the flight. It was also observed that in flying the approach, the crew are often required to *"optimise the published approach procedure"*. Following from this, the Head of Procedures remarked on certain weaknesses in relation to the airline's LOSA

evaluation, in terms of adequately representing the professionalism of crews flying the Alta approach. These issues are interesting in relation to (1) the development of a general model of Flight Crew task performance (i.e. use of procedures), (2) the advancement of a model of the pre-flight, flight planning and briefing task, and (3) the identification of the requirements for an improved pre-flight, briefing tool. As such, it was decided to investigate the Alta approach and the related LOSA report, in more detail.

Objectives

The specific objective of the Alta/LOSA study is to understand the constraints that apply to Flight Crew in terms of flying the Alta approach, the role of briefing in relation to the ALTA approach and the airline's experience with the LOSA methodology.

Method

The research methodology involved a mix of document analysis and participant interviews. First, the researcher reviewed all relevant flight operations documentation, including information about Stable Approach Procedures. A copy of the airline's confidential LOSA report was also obtained and reviewed.

The researcher then conducted interviews with two Pilots – one of whom was the Head of Procedures at the airline, while the other was a First Officer. In both cases, these participants had attended the process workshop. As part of this, the Researcher posed questions in relation to the nature of the approach procedure, the role of briefing and the use of specific tools. Questions were also posed in relation to Pilot improvisation of SOP in different contexts. Lastly, questions were posed in relation to LOSA evaluation undertaken by the airline in 2003.

Interview data was recorded using pencil and paper. This data was analysed in relation to several core themes, (1) overall Flight Crew task, (2) pre-flight, flight planning and briefing task, and (3) implications for the introduction of new briefing tool. On completion of this, specific HILAS reports were written. These reports were reviewed by airline representatives and feedback was provided.

Prior to the development of scenarios and prototypes for the new electronic briefing tool, these research findings were co-related to the other findings of Study 3 (i.e. Study 3:1 and Study 3:3), the findings of the processing mapping study (i.e. Study 1), the Flight Planning Study (i.e. Study 2), and the Flight Crew task analysis study (i.e. Study 4).

Participants

This involved two participants. The breakdown of participants is outlined in Table 15 below.

Table 15: Breakdown of Participants (Study 3:2)

Method	Airline Ref	Participant Number	Role/Function
Interviews	Airline 2	1	Head of Procedures
	Airline 2	2	First Officer

Results

The Alta route is flown by specifically trained Flight Crew only. Most Pilots would not have experience of making a night circling approach in bad weather. Despite training and experience, the approach is quite stressful.

It was stated that *"flying the Alta approach begins at the flight planning/briefing session before the flight"*. The airline's Dispatch Department provide the crew with special back-up information to support the pre-flight briefing. This includes generic operational and safety information, special procedures for the approach, and information about any particular issues to be taken into account in terms of the approach. Critically, the crew review all relevant flight information and agree on a strategy for flying the approach. As part of the briefing, the crew identify any threats that either currently apply or may potentially apply.

Both participants noted that the stable approach procedure cannot be followed at certain airports in northern Norway, and in other parts of Scandinavia. In such cases, Flight Crew make an assessment of the situation and optimise procedures taking into account their own area knowledge and personal experience/expertise. To explain this, the Head of Procedures/Management Pilot explained the constraints facing Flight Crew flying the Alta approach, and typical strategies/workarounds employed. The following is a summary of these constraints as relayed by the Head of Procedures.

"Firstly, the main approach procedure to Alta is a right hand circuit. There are no instrument approach procedures to runway 29. However, a circling procedure is established and is often used. The runway is only visible to the First Officer when approaching Alta (the runway is difficult to see from the Captain's or left side due to the curve in the round circle approach). The complex terrain (e.g. water and mountains) makes this a difficult approach to fly. The airport is situated at sea level by the estuary of the Alta River. Hills and mountains rising up to 3770 feet surround the airport within 12 nautical miles. Navigation aids are not always available in this terrain. Further, adverse weather conditions are often experienced, especially in winter. Sudden wind changes and/or strong winds can make it difficult for crew to maintain the profile plan. If it is snowing, visibility is reduced considerably. Daytime and night flying present different challenges. Therefore it is important to maintain terrain/traffic

awareness, in reduced visibility conditions. Routinely, adverse runway conditions apply which impact breaking action (e.g. slippery runways). Landing on a slippery runway requires the aircraft to arrive over the threshold at the correct height and speed and with the correct landing technique. "

Both the Head of Procedures and the First Officer stated that crews utilize key non technical skills in flying this approach. The Alta approach requires high co-operation/co-ordination and communication both between Flight Crew (Pilot Flying and Pilot Monitoring) and between Flight Crew and ATC. In addition, strong planning is required to deal with contingency. Crews continuously *"think ahead and manage information in relation to alternates, weather and the runway"*. This necessitates ongoing briefing between crews in terms of planning and agreeing next steps/actions. In this regard, the crew explicitly use CRM and TEM strategies.

The Head of Procedures remarked that *"The approach requires a balance between flying inside and flying outside"*. Here, cockpit tools provide considerable task support. In particular, the Precision Approach Path Indicator (PAPI) is used to determine the aircraft location (e.g. whether they are on or off the glide path). The availability and accuracy of weather information is also critical. Environmental conditions can change en route. Crews must ensure that they have all the latest information regarding airport conditions (i.e. runway condition and weather). Typically, crews obtain the latest weather and runway information fifteen minutes before top of descent. Where available, the Pilot Monitoring uses the ATIS service, to obtain the latest information. This information is used for landing calculations. Further, crew obtain navigational information and procedures from a range of paper charts. Specifically, crews refer to Standard Terminal Arrival Route (STARs) and Instrument Approach Procedures (IAPs) - for instrument approach information (i.e. altitudes and flight profile). Also, crew refer to Terminal Charts for airport and taxi-route layout information. En route charts (usually IFR) are used for en route navigation.

In relation to the Alta approach, the management Pilot alluded to certain crew strategies in optimising aircraft landing and runway roll out. Flight Crew prefer to have the full runway space in front of them. Instead of landing half way down the runway (and not using large space of under-run as outlined in procedures), pilots drop down early to optimise runway space. This is especially so when landing in tough weather conditions (i.e. consideration of braking action if slippery runway) or if the aircraft landing weight is high (i.e. impact on speed and time for landing). As stated by the Head of Procedures: *"This reflects a strong belief on the part of Flight Crew that this improves the procedure and is better for both passengers and the company"*. From the Pilots' perspective, this extra space provides a safety cushion. However, according to stable approach criteria this means unstabilising the approach. Further, insofar as these strategies fail to comply with company SOP, they can be characterized as intentional non compliance.

Although crew optimization of procedures results in a deviation from SOPs, both participants agreed that the optimisation of procedures in such contexts is acceptable. Yet, as pointed out by the Head of Procedures, *"this presents certain problems from a performance evaluation perspective"*. Typically, performance evaluation tools rate performance in terms of conformance to SOPs. Accordingly, if crews fail to follow the procedure, their performance is interpreted as unsatisfactory (i.e. procedural non compliance). Further, if this deviation is accompanied by an inappropriate aircraft state (i.e. inappropriate landing speed, or unstable approach) a safety critical event is deemed to have occurred.

In explaining this, the Head of Procedures elaborated on the airline's experience using the LOSA methodology, and specifically, certain weaknesses identified by the airline with this methodology and the associated 'LOSA report'. A LOSA evaluation was undertaken by the airline in 2003. The ensuing report highlighted a number of Flight Crew performance problems including, (1) procedural drift, (2) procedural non compliance (intentional and non intentional) and (3) inappropriate aircraft states including a large number of unstabilised approaches. In relation to Alta flights, the LOSA report *"indicated a pattern of unstabilised approaches"*. The Head of Procedures noted that the LOSA framework *"does not account for appropriate deviations from procedures"*. Yet, the Alta approach requires Flight Crew to optimise procedures in terms of their specific situation, to ensure that the aircraft lands safely. From a LOSA perspective, this is interpreted as intentional non compliance. However, as pointed out by the Head of Procedures: *"certain actions deviate from standard operating procedures but are considered acceptable and even optimal, given an understanding of the specific operating environment and situation"*. In this regard, a different evaluation and reporting methodology might tell an alternative story about crews landing in Alta. Such a methodology might suggest that in this case, crew are doing a good job (i.e. adapting procedures and managing contingency) despite the difficulties they encounter.

Further, as reported by the Head of Procedures: "To properly evaluate Flight Crew task activity, we must understand the context in which actions (errors or otherwise) are performed". Many things happen in relation to other processes that affect flight crew behaviour. This includes ATC, Maintenance and Co-ordinator actions. As stated by the Head of Procedures: "This information needs to be captured and related to Flight Crew performance".

5. STUDY 3:3 – CRM/TEM

Research Design

Background

Throughout the process workshops participants highlighted the importance of CRM training. Also, in workshops 2, 3, 4 and 5, participants directly referred to the concept of risk and specific TEM concepts. Thus, it was decided to explore CRM training in more detail. Further, during the workshop with Airline 5, participants alluded to certain new tools currently being advanced by the airline, which are inspired by CRM theory. This includes (1) the pre flight, CRM briefing guide and (2) the post flight voluntary reporting paper form. Potentially, these tools are relevant to the design of an improved pre-flight, flight planning and briefing tool. As such, it is necessary to elicit more information about these tools.

Objectives

The specific objectives of the CRM/TEM study included:

- To understand CRM/TEM training approaches
- To review the CRM briefing guide developed by the airline
- To review the TEM reporting template developed by the airline.

Method

Overview

This research was conducted with Airline 5 only. Overall, the research design comprised a mix of group interviews/workshops involving four participants, the observation of one CRM session, and two follow up interviews with two participants. In relation to the group interview/workshop and the follow up user interviews, all of the participants had previously attended the airline process workshop.

Group Session

A group workshop was conducted with four members of the CRM training team at the airline's offices. Before the interview commenced, the researcher explained the interview purpose and reminded participants about the confidentiality of interview findings. Participants were then asked a series of open questions. This included questions relating to the use of CRM and TEM concepts in Flight Crew training sessions, and how this theory influences actual operational performance. Questions were also posed in relation to the CRM briefing guide and the TEM template advanced by the airline's CRM Department. Participant feedback was recorded using a pencil and paper. Participant names and roles were

recorded during the interview. After the session, all transcripts were de-identified (i.e. participant name but not role).

Observation

The researcher sat in on a CRM training session with Pilots. This session was conducted in Spanish, although certain CRM examples were reviewed in English. The Researcher recorded all observations and notes using a pencil and paper.

Second Round Interviews

In addition, interviews were conducted with two Pilots, involved in the group session. In this case, participants were asked follow questions, in relation to issues which arose in both the group interview session, and in the observation of the CRM training. Participant feedback was recorded using a pencil and paper. Participant names and roles were recorded during the interview. After the session, all transcripts were de-identified (i.e. participant name but not role).

Data Analysis

Overall, the data captured was analysed in relation to three themes. This includes: (1) the use of CRM concept in training, (2) the nature of the CRM pre-flight briefing tool and the implications for the design of an improved briefing tool, and (3) the nature of the TEM reporting tool and the implications for the design of an improved briefing tool.

Participants

This study involved the participation of 4 participants. The breakdown of participants is provided in Table 16 below.

Table 16: Breakdown of Participants (Study 3:3)

Method	Airline Ref	Participant Number	Role/Function
Group Workshop	Airline 5	1	Captain/CRM Trainer
	Airline 5	2	First Officer/CRM Trainer
	Airline 5	3	First Officer/CRM Trainer
	Airline 5	4	First Officer/CRM Trainer
Second Round Interviews	Airline 5	1 (Same as previous)	Captain/CRM Trainer
	Airline 5	2 (Same as previous)	First Officer/CRM Trainer

Results

CRM Training

CRM training is provided by both human factors specialists from the Safety Department and by Flight Crew who have taken special CRM training courses. In relation to Flight Crew, this includes both First Officers and Captains. It was stated that *"the use of specially trained operational crew lends credibility to the training"*. Further, it ensures that *"CRM training addresses real world operational issues in a manner that make sense to operational crew"*.

Training material is based on two sources. Firstly, the CRM department compiles materials based on the guidance provided in the existing CRM literature. Further, training is devised following feedback from the analysis of airline performance/safety management data, by Safety personnel.

CRM training attempts to explain the overall CRM problem, and how best to deploy CRM behaviours in operational practice. Flight Crew are introduced to a number of key CRM concepts and associated crew strategies during the course of CRM training. Central to this, is the provision of training in relation to promoting teamwork. As stated by one participant, *"the quality of cockpit communication has an impact on team work"*. Further, *"complacency in relation to the importance of CRM practices has a negative effect on team efforts"*. Moreover, as observed by another participant *"the way in which crewmembers approach or respond to each other has a critical effect on team building and team results"*. The importance of team formation is explained. Further, the concept of joint situation awareness and situation assessment is also reviewed.

All four participants noted that the specific training material devised by the airline highlights the important role of briefing throughout the flight operation. In this respect, the qualities of good briefings and team decision making are analysed. Here, Pilots are invited to discuss examples from their own operational experience. Further, the specific qualities of the pre-flight, flight planning and briefing session, are also outlined. As noted by one participant: *"If performed properly, one of the results of the pre-flight, flight planning and briefing task is a well functioning team"*.

As part of this training, instructors review safety case studies prepared by the airline's safety department. Typically, these focus on an issue or series of issues relating to problems reported by a specific fleet. Firstly, crew are presented with an account of an incident or safety critical event. In certain cases, crews are furnished with high level FDM statistics and a visualisation of the flight profile. This facilitates comprehension of the relationship between human factors issues and aircraft states. Following this, the crew review the specific strategies adopted by the flight team, as reported in the relevant flight report, and the outcome of the event. Crews are then asked to evaluate the strategies used, and where

relevant, suggest alternative strategies. Usually, this leads to a discussion of best practice related to both CRM/TEM procedures and broader operating procedures. In this context, the problem of procedural drift is often addressed.

Further, it was stated that CRM training often involves both Cabin Crew and Flight Crew. As noted by one CRM trainer "combined crew training is useful in terms of promoting teamwork between the cabin and the cockpit, and communicating how and why specific communication breakdowns between the cabin and the cockpit team occur".

CRM Task Support Tools

Introduction

During the interviews, participants referred to two new task support tools that have been introduced by the CRM and Safety team. These tools draw upon specific CRM and TEM training concepts. In so doing, they actively encourage Pilots to use relevant CRM and TEM training concepts, during operations.

Briefing Guide/Checklist

The CRM and Safety team have recently introduced a briefing guide, premised on best practice CRM concepts, for use by Flight Crew. The objective of the guide is to foster crew CRM awareness and specifically to support crew briefing, the development of a common situation picture and team decision making. The guide describes what information the briefing should include. Briefing information is presented on an A 6 sized laminated piece of paper. The idea is that crews refer to this at the pre-flight, flight planning and briefing stage, in the same manner as they might refer to a checklist. This guide is slowly being introduced to crew, as part of CRM training sessions. To date, Flight Crew have received a copy of the guide and a full briefing as to it use. Flight Crew are invited to refer to the guide during the operation. Currently, the use of the guide is optional and is not formalised in SOPs.

TEM Briefing and Reporting

Further, the CRM and Safety team have developed an optional paper TEM briefing and reporting form, for use by Flight Crew. This form is predicated on the threat and error management model, and is designed to support two activities – namely briefing and reporting. From a graphical perspective, the template is divided into three sections – each section referring to a specific flight/operational phase. This includes: pre-flight/briefing and planning, flight execution/cruise and flight execution/top of descent. Each flight phase column is divided into two further columns – one for threats and one for the management of threats. Further, threats are organised into three categories - (1) crew, (2) aircraft and (3) environment. This specific taxonomy reflects crew mental models of threats, as established in recent research conducted by the safety department. An example of a TEM template is provided in Figure 1 below.

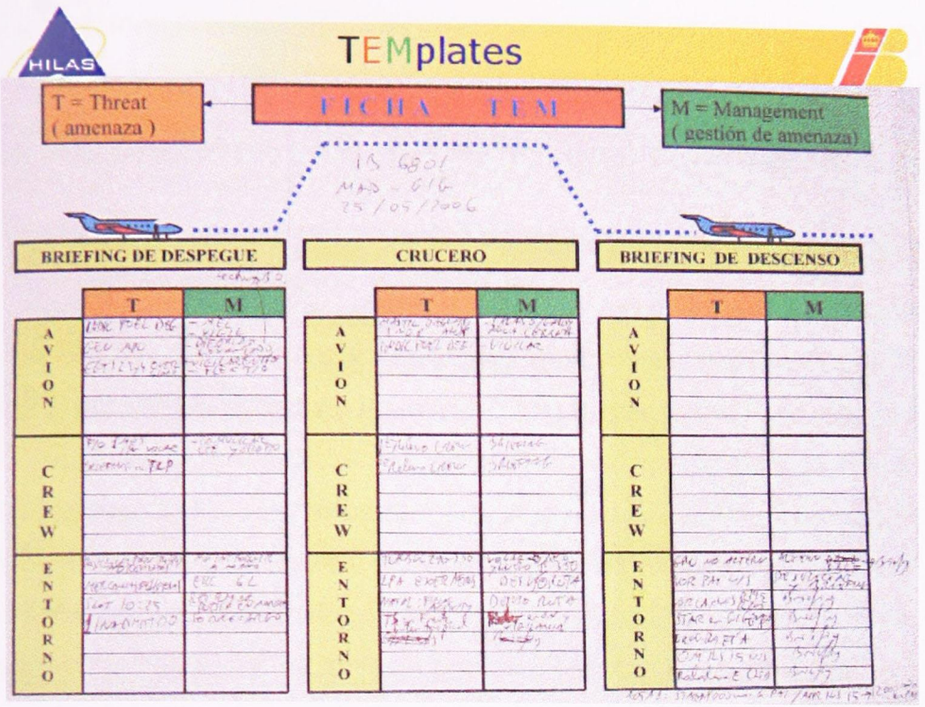

Figure 1: TEM Template (Study 3:3)

At the pre flight stage, crew are encouraged to brief on the specific flight threats that they have identified and the related strategies they expect to use to manage these threats. Crews are then asked to record this information on the paper form. During flight (e.g. subsequent two flight phases), crew record any additional threats encountered and how they were actually handled. The threat management reporting section can include information about errors made. At the end of the flight, crew review all of the information entered in the report for completion purposes.

In addition to supporting the application of TEM concepts in real practice, the template has two other benefits. Following their flight, the crew can send the completed form to their airline's safety department for analysis. As such, the Safety department obtains a picture of real world operational threats and how they are handled. This data is used for safety/risk management and organisational learning purposes. The information gathered is also relevant to crew CRM and technical training. As stressed by one participant, *"Reports data provides training personnel with feedback as to how real world problems are routinely managed by Flight Crew*".

Currently, this tool is being introduced during CRM training sessions and paper copies are available at the Safety Office. Participants observed that it might be useful to have an electronic version of this tool available on the EFB. This would facilitate fast data entry for Pilots. Further, it would enable more efficient analysis by the safety team. Participants also noted that Cabin Crew and other operational personnel might complete an equivalent form.

6. DISCUSSION

Process Design Problems & Improvement Recommendations

Following the theoretical principles outlined by Turner (1978) in relation to information disasters, and more recently, the research of Weick and Roberts (1993) in relation to high reliability organisations, one can argue that information pertaining to both actual and potential safety issues/threats, and the management of these, should be communicated to the right personnel, at the right time. Study 3:1 points to certain weaknesses in existing feedback processes. Feedback from participants across the three airlines suggests that these airlines require improved processes and tools, to support the communication of safety analysis findings to relevant operational functions. Nonetheless, it should be noted that these interviews were quite high level. Detailed process mapping was not undertaken. Further, the specific nature of existing process design problems related to the communication of safety information were not explored in huge detail. However, similar conclusions have been drawn by other researcher's working in the HILAS project, following from a more detailed analysis of existing airline safety/risk management processes (Cahill and Losa, 2008; McDonald, 2009). As reported by these researchers, this has resulted in the specification of a new SMS process and related technology tool concepts, to support (1) the gathering, integration and assessment of all relevant airline safety and operational data, (2) the assessment of the safety status of the operation, and (3) the communication of relevant findings to different stakeholders (Cahill and Losa, 2008; McDonald, 2009). Moreover, these findings accord with the SMS process principles as defined by ICAO (2006, 2009). Thus, taking this into account both the theoretical principles outlined above, specific SMS guidelines, and the broader research conducted in the HILAS project, it seems reasonable to argue that existing airline SMS processes might be enhanced, so that (1) Flight Crew receive all relevant safety/risk information pertaining to their flight, (2) Flight Planning personnel obtain all relevant safety/threats information, to support more intelligent aircraft pairing and rostering processes, and (3) Dispatchers obtain relevant safety/risk information to support the development of an intelligent, risk based Flight Plan.

Flight Crew Task

Collectively, the three sub-studies serve to extend and validate the findings of the first study, in relation to the role of procedures in operations. As evidenced in Study 3:2 in relation to the Alta approach, although procedures are important, they are not always followed. This is not always due to crew complacency, as suggested by Helmreich et al. (1999). Rather, this often reflects crew professionalism in terms of optimising procedures to support a safe outcome. As highlighted in study 3.2, this is a requirement of flying in particular operating conditions.

Further, in agreement with Johnston's account (2003), this requires considerable expertise on behalf of the crew. In this way, performance cannot always be evaluated in terms of procedures, as proposed in the LOSA methodology. As illustrated in relation to the Alta approach, crew actions may deviate from standard operating procedures, but such deviations are considered acceptable and even optimal, given an understanding of the particular operating environment and situation.

Further, this research emphasizes the importance of CRM and specifically TEM training concepts. As demonstrated in study 3:2, these concepts are utilized in operational practice. Specifically, crew flying the Alta approach perform a special briefing in advance of the flight. This ensures that all information pertaining to potential flight threats and the peculiarities of the operating environment is considered by Flight Crew in advance of the flight. Further, TEM behaviours are utilized at key points in the flight.

Nonetheless, the crew require significant backup support, to manage the complexity of certain operation situations, such as flying the Alta approach. In this regard, Study 3:2 highlights the critical role of tools, in relation to supporting task performance. As evidenced in this research, the special briefing package provided to crews flying the Alta approach provides a key task support function.

Moreover, as highlighted in both Study 3:2 and Study 3:3, Flight Crew task performance is highly collaborative. As evidenced in Study 3:2, the quality of cockpit teamwork has an impact on the flight outcome. Further, the task contributions of other operational agents which interface with Flight Crew have an impact on Flight Crew task activity. This therefore provides the rationale for CRM behaviour, as pointed out by participants in Study 3:3.

Pre-flight, Flight Planning and Briefing Task

Study 3:2 and 3:3 highlight the critical role of the pre-flight, flight planning and briefing task both in terms of cementing team concepts, managing operational complexity and managing workload.

Research with Airline Two (Study 3:2), indicates that Flight Crew perform a special briefing for certain flights in Northern Norway. Further, it was noted that the Alta approach starts with the performance of the pre-flight, flight planning briefing task. In this way, the pre-flight briefing is central to the execution of the approach task. Here, we can refer to the concept of task dependencies as outlined in Study 1. As shown, the quality of the pre-flight briefing impacts on other tasks performance later in the flight. Thus, a good quality briefing supports workload management, and later task performance.

In support of CRM theory, interviews with CRM personnel at Airline 5 (Study 3:3), highlight the role of pre-flight, flight planning and briefing task in relation to fostering teamwork.

Although these participants did not explicitly allude to complacency issues in relation to the requirement to brief, participants pointed to general problems concerning crew commitment to the practice of CRM procedures. As shown, Airline 5 has attempted to tackle these issues, in term of the introduction of a pre-flight briefing guide. This is discussed in more detail below.

Requirements for New Tool to Support Pre-flight, Flight Planning and Briefing Task

In Study 1, it was noted that to date, Flight Deck researchers have not focussed on making improvements to the existing flight plan. As evidenced in this research, airline operators appear to be taking a lead here. As testified in research with Airline 2 as part of Study 3:2, this airline provides additional task support information to Flight Crew flying certain complex routes in Northern Norway. For these routes, the standard flight plan is extended to include generic information about the approach, and specific safety issues to be considered. Potentially, a new electronic briefing tool might extend this approach for routine and non routine flights.

Further, as evidenced in research with Airline 5 as part of Study 3:3, it appears that the airlines are taking a lead, in term of advancing new tools which draw upon CRM/TEM training frameworks. As demonstrated in Study 3:3, Airline 5 has introduced a new briefing guide, to foster crew awareness as to the qualities of a good briefing. Moreover, this airline has introduced a new voluntary briefing and reporting form, premised on TEM concepts. Potentially, certain aspects of both tool concepts might be embedded in the new electronic flight planning and briefing tool. Specifically, the crew briefing checklist might be exploited, to help focus the crew's attention on the requirement to brief and the importance of teamwork. Further, the TEM classification scheme (i.e. crew, aircraft and environment) embedded in the airline's briefing and reporting template might be replicated in an improved briefing tool. That is, such a tool might structure flight specific threats information, in terms of three categories namely - crew, aircraft and environment.

Although CRM and TEM behaviours support the management of operational and environmental complexity, these form one aspect of both the crew's and the broader airline's safety strategy. As shown, safety also involves making use of all relevant safety and operational data, at the pre-flight stage. Thus, the findings of Study 3:2 in relation to the important role of the pre-flight, flight planning and briefing task, and the enhanced briefing package provided to Flight Crew lend credibility to the proposal to introduce enhanced task support tools at the pre-flight stage.

Study 3:1 highlights certain weaknesses in relation to the provision of safety/risk feedback to different Flight Planning functions, and to Flight Crew. Evidently, improvements are required

to existing SMS processes, to ensure that all personnel obtain safety/risk feedback, at the right time, and in the right format. In relation to Flight Crew, new feedback mechanisms are required, above and beyond existing approaches. Ideally, an improved briefing package might feature real time information about the risk status of the flight, and any known or potential flight threats, for routine and non routine flights. The presentation of flight specific, real-time threats information in all flight plans represents an extension of the approach undertaken by Airline 2 as outlined above. However, as highlighted in Study 3:1, to successfully implement such a system, the airline needs to improve existing processes and tools relating to the gathering of operational and safety data. As highlighted in Study 3:1 this necessitates improvements in existing routine reporting rates. Poor reporting rates impact on the ability of the airline to fully analyse both operational and safety problems. Thus, to introduce an improved briefing tool, these airlines need to address problems relating to crew reporting. As demonstrated in Study 3:1, the provision of improved access to reports, and improved feedback about the safety actions following from reports, might motivate Flight Crew to report above the mandatory requirement.

7. CONCLUSIONS

Collectively, these three sub-studies illuminate the complex role of procedures in operations, the importance of the pre-flight, flight planning and briefing task, and the requirements for improved SMS processes and tools, to support the provision of the safety/risk feedback to relevant operational functions, including Flight Crew.

Study3:1 provides a high level insight into the nature of airline performance/safety management processes and tools, and recent SMS developments. In particular, this study suggests potential requirements to improve existing airline processes related to the communication of safety/risk feedback to relevant airline functions, as part of the broader SMS process improvements. This has an upshot for the design of new tools supporting Flight Crew performance of the pre-flight, flight planning and briefing task. An improved tool might feature flight specific risk/TEM information, following from reactive and proactive risk assessments. However, certain caveats must be noted. This research was quite high level. More detailed research concerning the nature of existing SMS feedback mechanisms, the requirements for improved feedback mechanisms, and the feasibility of relaying risk assessment information to Flight Crew at the pre-flight stage, is required.

Study 3:3 illuminates the nature of the Flight Crew task and specifically, the role of procedures in operations. Specifically, it points to the degree to which task performance involves managing different levels of operational and environmental complexity. As shown, this often necessitates the optimisation of procedures, to meet the demands of the particular situation. Also, this study illustrates the importance of crew use of CRM and TEM

behaviours, in terms of managing different levels of complexity. Feedback about crew briefing procedures at the pre-flight stage in relation to the Alta approach underscores the importance of the pre-flight briefing task in relation to developing team concepts, supporting situation assessment, and managing workload. Lastly, feedback in relation to the introduction of an enhanced briefing package for complex routes/approaches such as Alta, lends credibility to the suggestion to enhance the existing briefing package.

Study 3:3 provides background information about airline's CRM training programme. Further, it provides information about certain new tools developed by the airline's CRM department to assist crew application of CRM and TEM concepts in operational practice. Crucially, these tool concepts indicate a potential way forward in relation to the introduction of new tools assisting Flight Crew performance of the pre-flight, flight planning and briefing task.

It should be noted that although the collective findings of this study provide an indication of a potential way forward in terms of the introduction of a new tool assisting Flight Crew performance of the pre-flight, flight planning and briefing task, this research does not provide concrete guidance as to particular tool requirements and how they might be implemented. In terms of the latter, this concerns the specification of both the HCI tool concept, and the underlying airline operational and organisational processes, necessary to the implementation of this tool at an airline. Both the nature of the pre-flight, flight planning and briefing task, and the requirements for improved tools must be investigated in more detail. This is addressed in Study 4. Specific tool concepts must be prototyped and evaluated. This research is undertaken in Studies 5 and 6. Further, the new underlying process requirements must be specified. This research is undertaken in Study 6.

Study 4: Flight Crew Task Analysis & the Identification of New Tool Requirements

1. CHAPTER INTRODUCTION

This chapter reports on the findings of the fourth HILAS case study: Flight Crew task, tools and information analysis. Study 1 highlighted the socio-technical nature of Flight Crew task performance and issues related to procedural drift. These aspects of Flight Crew task performance warrant further investigation. Further, this study illuminated the importance of the pre-flight, flight planning and briefing task in relation to the wider Flight Crew task, the process logic underpinning Flight Crew performance of this task, and several task execution problems. However, specific task dimensions and associated task problems were not explored in detail. Moreover, this study suggested certain high level requirements for an improved tool supporting Flight Crew performance of this task, and mitigating certain wider process design problems. Again, this was not explored in much detail. Overall, a closer examination of this task, specific task problems and future tool requirements is required.

2. INTRODUCTION

Flight Crew Tools

Flight Crew tool design has its basis in the current flight operations concept, and the related distribution of task functions between Flight Crew, ATC and technology (i.e. aircraft and IT systems used by both Flight Crew and ATC) in relation to flight management and aircraft separation, taking into account existing technology capability. Specific tool concepts have emerged based on an understanding of the Flight Crew task and associated information requirements within this overall framework. Several part task tools are used at different points in the flight operation. A summary of these tools is provided in Appendix 4. Certain tools are used throughout the flight, while others are used at particular flight phases. This includes a range of paper tools (i.e. charts, checklists and reports), aircraft equipment and IT systems.

A number of advanced tools are currently is use and/or in the process of being introduced to commercial cockpits. In terms of hardware, this includes Electronic Flight Bags (EFBs) and Heads up Displays (HUDs). New display technologies are also being advanced. Further, a range of software applications/information displays which exploit these new display

technologies have been developed. Many of these applications are accessible using EFBs and HUDs.

Of most relevance to this thesis is the introduction of Electronic Flight Bags (EFBs). As stated in Study 1, the EFB presents supplemental flight information in digital format. This new EFB format provides opportunities to exploit information presentation functions not possible with paper (Chandra, Yeh, Riley & Mangold, 2003). Further, this new format potentially facilitates improvements in information access, and in the provision of real-time information updates. To date, there is limited information available on the use of EFBs in commercial operations. Although the high level human factors requirements for EFBs have been specified (Chandra, Yeh, Riley & Mangold, 2003), this research does not address how EFBs might be used to solve existing process and task problems. For example, the authors do not explain how EFBs might be used to facilitate teamwork and information sharing across different operational agents. Further, do the existing EFBs provided by the different avionics companies meet airline requirements? What are the problems to be addressed from an airline perspective, and how might future EFBs be designed to ameliorate these problems? This requires closer examination.

New Cockpit Concepts (Commercial)

Many new technologies, hardware concepts and software applications have been introduced to commercial cockpits. In terms of technologies, this includes cockpit display technologies, automation technologies (Parasuraman, Mouloua & Hilburn, 1999) and data link technologies (Ivancic, 2006), supporting the implementation of the Free Flight concept. New hardware concepts comprise Helmet Mounted Displays (Rash, 2001), Speech/Voice Input and Output, and the Tracker Ball. Lastly, the new software applications/information applications assist several Flight Crew task functions such as flight management (Doherty and Wickens, 2001; Flohr and Huisman, 1997; Kubbat, Lenhart & von Viebahn, 1998; Sachs, Dobler, and Hermle, 1998; Theunissen, 1997; von Viebahn, 1998) and certain non technical dimensions of Flight Crew task activity. In relation to the latter, this includes situation assessment (Solodiloval, Lintern & Johnston, 2003), and task management (Funk and Braune, 1999).

Although many new tools have been introduced in commercial cockpits, these tools do not solve certain critical Flight Crew task problems, linking to the design of the broader operational and organisational system, in which Flight Crew perform their tasks. From an operational perspective, these new tool/technology concepts fall short of assisting Flight Crew information sharing/communication with other roles during the operation (i.e. Dispatch and Flight Operations Control). In terms of broader organisational functions, these tools do not address Flight Crew safety tasks such as briefing and reporting. As such, these new

tools appear divorced from the operational and organisational context in which Flight Crew perform their tasks. Critically, new technology should address real world issues and ameliorate existing task problems and/or tool weaknesses. Arguably, new tool development can be characterized as technology driven, as opposed to operationally driven. Who is setting the tools/technology research agenda? Human Factors researchers must question whether tool development is premised on improving Flight Crew performance of the existing task, or enhancing existing technology/systems, given new technology capability?

New Operational Concepts

In an effort to overcome some of the Flight Crew task problems linked to the design of the current flight operations concept, new flight operations concepts along with the respective ATM and Flight Crew technology solutions, have been advanced. This includes the Single European Sky (Eurocontrol, 2009) and the associated Free Flight concept (Johnson, Battiste and Bochow, 1999), and the movement from a two crew cockpit to single crew and/or fully automated flight.

A critical feature of the Free Flight concept is the proposal to share flight information across all relevant stakeholders (i.e. ATC, Flight Crew, Airport Operator and Ground Operations). To date, technology development has focussed on implementing new ground/air data links to assist information sharing between Flight Crew and ATC, during the flight execution phase. As part of this, new Flight Crew/ATC functions in relation to navigation/routing and separation responsibility have been defined. Critically, these new concepts will require changes to existing airline processes related to the specification and signoff of the Flight Plan. Further, in addition to changing the Flight Crew/ATC relationship, the introduction of this new operational concept will impact on Flight Crew co-ordination with other operational roles, including Dispatch and Flight Operations Control. Currently, the operational and technology concepts advanced do not address Flight Crew information sharing/communication (1) with other roles, and/or (2) at other points in the flight operations timeline, including both pre-flight (e.g. briefing) and post flight (e.g. reporting). This includes Flight Crew information sharing with Dispatch, Flight Operations Control, Maintenance, Ground Handling, the Co-ordinator, Safety and other. These problems will need to be resolved. Nonetheless, there is much to learn from these initial concepts. In principle, the proposal to advance new technologies which enhance information sharing across the different stakeholders involved in the task activity (both directly and indirectly) seems a good idea. Potentially, the initial Free Flight Concepts might be further developed to take into account Flight Crew information sharing with relevant airline operational and organisational functions.

Recent research by Harris (2007; 2009) suggests a potential solution to the implementation of reduced crew operations following the Free Flight Concept. Harris (2007; 2009) envisages a solution involving changes to the composition of the Flight Crew team along with their role task functions. As defined by Harris (2009), the breakdown of crew functions might be structured as follows: one of crew member might focus on flight management and system management tasks, while the other crew member would focus on flight planning, communication, navigation and surveillance tasks. According to Harris (2009), this would necessitate a redesign of the cockpit area and associated technologies. However, it should be noted that these new role task functions do not alter the requirement for a full and detailed briefing between relevant team agents. Nonetheless, it may change the nature of the briefing process. That is, there may be changes in terms of who is making the briefing, the roles of the crew members in terms of making a briefing, what additional roles (i.e. non cockpit roles) are involved in the briefing, and how this is supported in terms of the HCI design of tools. Crucially, these changes still necessitate adequate task support for both crew members, in terms of managing the operation and co-ordinating relevant task and information inputs from team agents. Further, if single crew concepts are introduced, the need for enhanced task support will be even greater.

Weather Management Systems

Recent research in the weather domain illuminates the requirement to advance new Flight Crew tools which directly link to the broader airline operational and safety context (Dutcher, 2009; Dutcher and Doiran, 2008; Dutcher, 2005). Dutcher points to the requirement to develop a weather management system (WMS) designed to manage the impact of weather hazards on flight operations (2009; 2005). This system would provide a risk based assessment of weather. According to Dutcher (2009), a keystone to the implementation of this WMS is the integration of the WMS with the airlines safety management system (SMS). In support of this, Dutcher (2003) has developed a weather analysis checklist and defined certain high level requirements for an improved SMS (2009). In principle, this risk assessment and associated information would be relayed to Flight Crew. However, Dutcher has not specified the particular mechanism for this. Nonetheless, this is a highly innovative approach. The proposal to advance new Flight Crew tools which resolve specific operational problems (i.e. weather management) and link to broader airline operations management and safety management systems illuminates a future direction for improved Flight Crew tools. Potentially, these integrated weather and safety management tool concepts might be implemented in an improved flight plan. That is, an improved flight plan might exploit broader airline safety/risk management outputs (i.e. not just weather risk analysis). This requires further research.

Relevant Tool Concepts (Other Domains)

Although research in the commercial domain has not focused on making improvements to the existing Flight Plan and/or, the provision of more general task support in relation to Flight Crew performance of the pre-flight, flight planning and briefing task, research in the general aviation and military domains, suggest a possible way forward.

Many commercial tools have been advanced in the general aviation domain providing task support for certain aspects of the pre-flight, flight planning and briefing task. Computer based electronic fight planning tools and/or EFBs allow general aviation Pilots to compile a Flight Plan. In both cases, an overall Flight Plan template is provided. This contains various flight plan fields, which the Pilot completes according to the specific flight context. More advanced tools provide recommendations in terms of routing and fuel requirements. Further, certain EFBs provide electronic access to en route maps and departure/approach charts. Also, general aviation Pilots can obtain real time weather information using commercial web applications.

In terms of military domain, new paper based tools have been advanced which support risk management activities on behalf of the Pilot, at the pre-flight stage (Loukopoulos, 2009). Pilots use these tools to identify and report on potential operational risks, and how they plan to manage them. In this way, these tools assist the Pilot in assessing the risk status of the operation and in establishing a go/no-go decision. Critically, these tools are used for both routine and non routine situations. Potentially, these tools might be developed in the context of commercial flight operations, to support Flight Crew risk assessment and briefing activities, at the pre-flight stage. This requires further research.

Lastly, advances in mobile computing, ubiquitous computing (Weiser and Brown, 1996) and computer based social networking, have changed the role of technology in our lives. In particular, such developments have set new expectations in terms of the potentialities for improved information access. These changes will influence and/or have influenced Pilot conceptual models of new technology. As such, these concepts may highlight new directions for improved tools, for use by Flight Crew at the pre-flight stage.

3. METHODOLOGY

Overview

This study involved two phases of research. In the first phase, the overall objective was to validate the findings of the process workshops in relation to Flight Crew task performance and to further develop the emerging Flight Crew task model – both in relation to the general model of the Flight Crew task, along with the specific model of the pre-flight, flight planning

and briefing task. Critically, jump-seat observations were used to capture information about actual task practice. This research was conducted with Airline 2 and Airline 5. The second phase of research was conducted with Airline 5 only. This phase focussed on advancing a more detailed understanding of the pre-flight, flight planning and briefing task, Flight Crew problems with existing briefing tools and Flight Crew requirements for improved tools. Further, Flight Crew experiences with new tools developed by the airline were also elucidated.

Research Design Phase 1

Objectives

The overall objective of the first phase of Flight Crew task analysis was to validate the findings of the process workshop and to bridge any gaps identified in this research. The specific objectives include:

- To validate the list of Flight Crew tasks at each critical point in the process, identifying task allocation in terms of rank (i.e. Captain and First Officer) and role (i.e. PF and PM), identifying key tasks (criticality, priority etc), ascertaining task relationships (running order or logic) and understanding task dependencies
- To understand the socio-technical nature of Flight Crew task performance
- To understand Flight Crew safety behaviour and in particular, the use of procedures and CRM/TEM behaviors
- To elicit more information about the pre-flight, flight planning and briefing task.

Method

Summary

Research was conducted with eleven participants – involving Flight Crew from both Airline 2 and Airline 5. First, a detailed interview was conducted with a First Officer from Airline 5. Following this, three jump-seat observations and follow up de-brief interviews were undertaken with one set of Flight Crew from Airline 5. Four jump-seat observations and follow up de-brief interviews, were then conducted with one set of crew from Airline 2. A further detailed interview was conducted with a First Officer from Airline 2. A walk-through of the pre-flight, flight planning and briefing process was also conducted with this First Officer. Also, two observations of pre-flight, flight planning and briefing task were undertaken with two sets of Flight Crew from Airline 2.

Interview (Airline Five)

Prior to embarking on the interview, the analysis outputs of the workshops (i.e. process gate templates), were simplified, to focus on the Flight Crew role. For each process gate, two sets of templates were produced. This included: (1) process gates and tasks and (2) detailed process gate and task information. For an example of these templates, please see Table 17 and Table 18 below.

Table 17: Template 1 - Process Gate and Tasks (Study 4)

Process gate				
List of Flight Crew Tasks				
Task Relationships (Running Order or Logic)				
List of Flight Crew Tasks (Role & Rank)	CPT	FO	PF	PNF
Key Tasks (Criticality, Complexity, Risk)	CPT	FO	PF	PNF

Table 18: Template 2 - Detailed Process Gate and Task Information (Study 4)

HIGH LEVEL PROCESS INFORMATION	
PROCESS PHASE	
PROCESS SUB-PHASE	
CRITICAL POINT	
PRIOR DEPENDENCIES	
TASK SCENARIOS	

TASK ENVIRONMENT
COCKPIT: ROLE, TASK, TOOLS INFORMATION

High Level Task	Specific Task No	Primary Role	Task	Tools	Other Role

COCKPIT: TASK RELATIONSHIPS
AFTER STATE & FUTURE DEPENDENCIES

Process	
Aircraft	
People	
Tools	
Environment	

KEY ISSUES, RISKS/THREATS, PROBLEMS ENCOUNTERED
WORKAROUNDS, IMPROVISATIONS, GOOD POINTS
FUTURE DEPENDENCIES
RATING OF CRITICAL POINT
CRITICAL TASKS

A detailed interview was conducted with a First Officer from Airline 5, over a three day period. The First Officer had attended the process workshop. The purpose of the interviews was to validate the findings of the process workshops and specifically, to understand the relationship between Flight Crew task performance and the design of the Active Flight Operations process. First, the high level process map for the Active Flight Operation, for Airline 5 was reviewed. Following this, the researcher presented the preliminary analysis outputs for each process gate. The participant reviewed both templates for each process gate – suggestions changes/updates and adding information as required.

Jump-seat Observations & De-brief Interview (Airline 2 and 5)

Jump-seat observations were conducted after the initial participant interview to elicit feedback about real world task practice – both in relation to the high level task and the specific, pre-flight, flight planning and briefing task.

Observations focussed on understanding the operational and environmental context for Flight Crew task performance and associated team work issues. Further, observations were used to elicit information about Flight Crew use of tools and information flow both within the cockpit and between Flight Crew and other operational roles. This follows from Hutchins (1995a; 1996) and Von Thayden's (2004) approach to analysing crew information behaviour.

The researcher flew in the jump-seat. At suitable moments during flight (i.e. cruise), the researcher posed questions in relation to task performance and information requirements. De-briefing interviews were conducted after the flight, with all crews. These interviews were used to elicit information about specific Pilot workflows and workarounds, and issues that arose during the course of the operation. In certain instances, additional informal interviews were conducted while travelling/over breakfast the following day. Participant names and roles were recorded during the observation. After the session, all transcripts were de-identified (e.g. participant name but not role).

Interview (Airline 2)

Following jump-seat observations with both airlines, an extensive interview was conducted with one Pilot from Airline 2. This Pilot had been involved in the process workshop for Airline 2. This interview focussed on unpacking issues identified in jump-seat observations with that airline.

Flight Planning & Briefing Walkthrough Procedure (Airline 2)

A walkthrough of the pre-flight, flight planning and briefing task was then conducted with the same First Officer from Airline 2. The First Officer demonstrated the electronic Flight Planning System. The First Officer then simulated the flight planning process for the Bodo and Alta flights. As part of this, the First Officer selected each function and explained how it is used from a flight planning and briefing perspective.

Observation of the Pre Flight, Flight Planning & Briefing Task at Crew Dispatch Room (Airline 2)

Lastly, two observations of the pre-flight, flight planning and briefing task were undertaken with Flight Crew from Airline 2. The observations took place in the crew centre of Airline 2. The Researcher observed the full briefing session and took notes.

Data Analysis

The two task analysis templates produced after the process workshops, were extended to reflect the overall findings of both the Flight Crew interviews and observations. This included a summary of Flight Crew tasks for each process gate, and a detailed analysis of this task picture for each process gate. This task analysis information is available on the CD accompanying this thesis. Further, the following high level process templates were advanced: (1) Process Gates: Flight Crew Communication with Other Roles, (2) Active Flight Operations: Process Gates, Task Dependencies, Blockers and Facilitators, and (3) Active Flight Operations: Process Gates and Associated States. The first of these is presented in Table 22, as part of the results section. The latter two are presented in Appendix 5 and Appendix 6.

A report was compiled summarizing the main research findings of this research, in terms of a model of Flight Crew task performance. This included an analysis of the core socio-technical dimensions of Flight Crew task performance (i.e. task and process, context, team dimensions and the use of tools), Flight Crew safety behaviour, task allocation and the relationship between task requirements and duty status. Further, an analysis of the pre-flight, flight planning and briefing task was advanced, to support the second phase of task analysis research. This included an analysis of the socio-technical dimensions of this task, a high level description of task workflows, and a preliminary analysis of tools and information resources.

Participants

Overall, this study involved eleven participants. A breakdown of participants is provided in Table 19 below.

Table 19: Participants, Phase 1 (Study 4)

Airline Ref	Task Analysis Case Study	Flight Crew Observation & De-brief Interviews	Task Analysis Interview	Flight Planning/Briefing Walkthrough	Dispatch Observation
Airline 5	1	3 flights, flights 1, 2, 3 One set of crew – 2 participants – participants 2 and 3	-	-	-
Airline 2	-	4 flights, flights 1, 2, 3, 4 One set of crew – 2 participants – participants 4 and 5 Crew change at flight four – participant 6	1 participant – participant 7	1 participant – participant 7 (same as interview)	2 flights – two sets of crews – participants 8, 9, 10 & 11

Research Design: Phase 2

Objectives

The specific objectives included:

- To further understand the nature of the pre-flight, flight planning and briefing task
- To understand crew use of the existing Flight Plan
- To understand existing task problems, what causes these problems, and how these problems might be ameliorated via the introduction of new task transforming tools
- To elicit feedback about Flight Crew requirements for improved tools, assisting the performance of the pre-flight, flight planning and briefing task
- To review crew experiences with the new tools advanced by Airline 5 (i.e. pre flight, briefing guide and TEM reporting form).

Method

Prior to embarking on the observations and interviews, a further task analysis template was developed. This presented more detailed information about the pre-flight, flight planning and briefing task, particularly in relation to tools and information usage. This template was populated with a high level summary of relevant task findings, from the first phase of research, and all prior studies (i.e. studies, 1, 2 and 3).

Six Flight Crew interviews were conducted with Airline 5 over two separate weeks during October 2006 and March 2007. The duration of each interview was approximately two hours. Participant interviews followed a semi structured format. Participant answers were recorded using pencil and paper.

First crews were briefed on the HILAS project. As part of this, the researcher explained the nature and status of project research and prior research conducted with the airline. Following this, the researcher explained the objectives and plan for the interview session. Crew profile information was then obtained (i.e. time with airline, crew rank, fleet, experience with other airlines). The researcher then posed specific task questions to the participant following the structure of the task analysis template especially designed for this purpose. Please see Appendix 7 for an example of the task analysis template. There was insufficient time to pose all template questions. As such, the interviews focussed on gathering information related to a subset of the template questions. Participants were asked questions related to task importance/significance, human factors dimensions of the task, task workflow and adherence to SOP, collaboration with other roles, use of TEM, task information requirements, information gaps, information sources, information classification and priority, specific use of tools and information resources, task facilitators, tasks problems, and the reasons for specific task problems. Further, the Researcher questioned Flight Crew participants about tool problems and requirements. Following this, the Researcher conducted a preliminary envisionment exercise. Participants were invited to consider how the existing briefing task might change given the introduction of new tools. Participants were then invited to draw high level concepts for improved tool user interfaces, using a pencil and paper. The researcher also drew certain concepts using a pencil and paper, to assist problem solving and communicate/share design ideas with participants. At the end of the interview, the researcher thanked the participant for their time, and explained the next steps for the project.

Data Analysis

Overall, the objective of the task analysis was to develop a model of the existing task and associated task problems, to support new tool envisionment and HCI design activities. First, task feedback was analysed in relation to several core themes. This included (1) task significance, (2) task workflows and the use of procedures, (3) performance shaping factors and their impact on task performance, (4) the use of CRM and TEM behaviours as part of task performance, (4) task facilitators and (5) task blockers and the reasons for this. In support of design activities, particular tools and information issues were then analysed in more detail. This included an analysis of the use of existing tools and information resources and associated problems, and the requirements for improved tools supporting Flight Crew performance of this task.

Participants

Overall this involved six participants – comprising four First Officers and two Captains. One of the Captains also worked as a Safety Officer. A breakdown of participants is provided in Table 20 below.

Table 20: Participants Phase 2 (Study 4)

Airline Ref	Week Ref	Participant Number	Role
Airline 5	1	1	First Officer
Airline 5	1	2	Captain/Safety Officer
Airline 5	2	3	First Officer
Airline 5	2	4	First Officer
Airline 5	2	5	First Officer
Airline 5	2	6	Captain

4. RESULTS: PHASE 1

Key Tasks

Flight Crew interviews and observations point to the importance of certain tasks. Broadly, this is consistent with the definition of key tasks, as emerged in Study 1. These are defined in Table 21 below. Overall research highlights the importance of crew briefings. This includes formal briefings (i.e. pre flight and top of descent), checklists briefings and informal briefings. Participants also highlighted the importance of Flight Crew co-ordination/communication with ATC and other operational agents. In relation to the latter, this includes: Dispatch, Maintenance, Co-ordinator, Flight Operations Control, Cabin Crew, and Ground Handing. Several flight management tasks (i.e. navigation, guidance and control) at different points in the flight operation were also emphasized. In terms of the flight timeline, this includes: taxi, takeoff, descent approach and landing, taxi-in and parking. Lastly, all participants stressed the essential role of reporting.

Table 21: Key Flight Crew Tasks (Study 4)

#	Process Phase/Timeline	Process Sub Phase	Process Gate	Key Tasks
1	Pre Flight	Dispatch	Crew Arrive	
			Flight dispatch/briefing	Pre-flight planning and briefing and associated fuel decision
			Combined Crew Meeting/Briefing	Flight Crew/Cabin Crew Briefing
		Aircraft Release & Turnaround	Aircraft technical status	Review & Signoff Aircraft Technical Status
			Doors Closed	Co-ordination/Communication with Ground Control
2	Flight Execution	Push-back, Taxi & Takeoff	Ready for push-back	Co-ordination/Communication with Ground Control
			Taxi	Airport Taxi Co-ordination/Communication with Ground Control Flight Management (Aircraft Navigation, Guidance and Control)
			Ready for takeoff	Co-ordination/Communication with Ground Control Flight Management (Aircraft Navigation, Guidance and Control)
			Takeoff	Decision to takeoff Decision to abort takeoff Flight Management (Aircraft Navigation, Guidance and Control)
		Climb	Initial Climb Complete: 10,000ft	Flight Management (Aircraft Navigation, Guidance and Control)
		Cruise	At Cruise Altitude	Flight Management (Aircraft Navigation, Guidance and Control) Co-ordination/Communication with Flight Operations Control ATC Co-ordination in relation to

				routing/flight plan changes during cruise
		Approach & Landing	Preparation for descent: Approach briefing	Flight Briefing at Top of Descent Decision to divert Flight Management (Aircraft Navigation, Guidance and Control) ATC Co-ordination in relation to routing/flight plan changes during approach & descent Co-ordination/Communication with Flight Operations Control Obtain latest weather information
			10,000 ft/Sterile Cockpit	Flight Management (Aircraft Navigation, Guidance and Control) ATC Co-ordination in relation to routing/flight plan changes during approach & descent Obtain latest weather information
			Commence Final Approach	Flight Management (Aircraft Navigation, Guidance and Control) ATC Co-ordination in relation to routing/flight plan changes during approach & descent
			1,000 ft	Flight Management (Aircraft Navigation, Guidance and Control) ATC Co-ordination in relation to routing/flight plan changes during approach & descent
			Decision to land	Flight Management (Aircraft Navigation, Guidance and Control) ATC Co-ordination in relation to routing/flight plan changes during approach & descent Decision to Land or Go-Around
			Landing & Rollout	CAT 111 Landing Landing & Roll out Ground Control Co-

				ordination/Communication
		Taxi		Airport Taxi Co-ordination/Communication with Ground Control Co-ordination/Communication with Flight Operations Control
3	Flight Review & Report		Flight Report	Flight Report (Operational) Flight Report (Safety)
			Handover to Next Crew	Informal communication with next crew regarding aircraft issues

Relationship between Task and Process (Active Flight Operation)

Flight Crew task workflows are structured according to the functional logic of the operational process. In principle, it is possible to associate/group tasks to specific process gates. However, this does not mean that tasks are associated with one process gate only. In certain cases, tasks start and finish during one process gate (i.e. takeoff briefing). In other cases, certain tasks commence at one process gate, but can continue right through other process gates (i.e. aircraft guidance and control). Further, the duration of tasks is not fixed. Tasks may commence at one process gate (i.e. aircraft technical status), but the finish time is determined by the scenario on the day (i.e. number of problems to be resolved and availability of Maintenance). As such, for each process gate we must distinguish: (1) ongoing tasks (carried over from previous process gate) and (2) new tasks (specific to that process gate). Nonetheless, at certain process gates, specific tasks must be accomplished, or the process will not move forward (i.e. flight briefing, aircraft tech status, board passengers and takeoff). As such, the completion of certain tasks becomes more or less important at different points in the operational timeline. Typically, if there is a technical issue, crews will proceed with the initial flight preparation tasks (i.e. cockpit checks, navigation systems initiation and flight briefing), with the expectation that the problem will be resolved. However, if the problem is serious, passengers are not boarded. To avoid delays, Flight Crew will attempt to make the same ATC window. However, if the problem persists, maintaining the ATC window becomes difficult. Preparations for engine start/push-back cannot commence until all technical problems are resolved. Task management strategies can mitigate the impact of certain problems. However, if the problem is serious, delays will ensue. Accordingly, for each process gate, (1) mandatory tasks and (2) optional tasks can be distinguished. It is critical that task requirements are managed, such that necessary process states are achieved, at

different points in the process. This provides a means for Flight Crew to assess what tasks to prioritize, so as to ensure the stability of the process (i.e. transition to next process gate). This requires strong task management skills on the part of Flight Crew.

Flight Crew operate in a multiple task environment. Within a process gate, task relationships are complex and it is not a simple sequential task picture. For example (1) certain tasks can run continuously (e.g. across time span for that process gate and as noted above into the next process gate), (2) some will occur at specific time points (i.e. as part of a task sequence and in parallel to other tasks) and (3) some will occur at any point in time across the time span for that process gate. Only one task - the Captain's passenger announcement call - was identified as independent of other tasks in terms of performance within a process gate. According to participants, all other tasks link to other tasks, are sequenced, or are context specific.

Many tasks run in parallel and are split between PF and PM. This includes high level tasks (i.e. aircraft navigation, guidance and control) and specific tasks (i.e. check weather information).

Interview feedback and jump-seat observations resulted in a more detailed picture of the range of states associated with each process gate. This includes process states, flight plan states, aircraft states, Flight Crew states, other crew states, and tools and information states. For more information, please see Appendix 6.

Team

Overall Team Concept

Flight Crew co-ordinate and communicate with different team members at different points in the operational timeline/process, as detailed in Table 22 below. Critically, the Pilot is the key co-ordinating interface across the different personnel involved in the Flight Operation. In this regard, a First Officer from Airline 5 stated: *"From Flight Operations perspective, the Pilot is considered the key engine of the operation".*

Table 22: Process Gates: Flight Crew Communication with Other Roles (Study 4)

#	Process Phase/Timeline	Process Sub Phase	Critical Point / Process Gate	Communication/Co-ordination (Other Roles)
1	Pre Flight	1 a: Dispatch	Crew Arrive	Cabin Crew
			Flight dispatch/briefing	Flight Operations Control (If Required) Dispatch (If Required)

			Combined Crew Meeting/Briefing	Cabin Crew
		1b: Aircraft Release & Turnaround	Aircraft technical status	Previous Crew (if aircraft change) Maintenance Co-ordinator Fueller Cabin Crew ATC/Ground Control Flight Operations Control (If Required)
			Doors Closed	Cabin Crew ATC/Ground Control Flight Operations Control (If Required)
2	Flight Execution	2a:Push-back, Taxi & Takeoff	Ready for push-back	ATC/Ground Control Tow truck driver and walker
			Taxi	Tow truck driver and walker ATC/Ground Control ATC/Tower
			Ready for takeoff	ATC/Tower
			Takeoff	ATC/Tower
		2b:Climb	Initial Climb Complete: 10,000ft	ATC/Tower ATC
			At Cruise Altitude	ATC Cabin Crew
		2c. Cruise	Navigation/Routing Checks	Cabin Crew ATC Flight Operations Control
		2d. Approach & Landing	Preparation for descent: Approach briefing	ATC Flight Operations Control

			10,000 ft/Sterile Cockpit	ATC/Approach
			Final Approach Fix	ATC/Approach
			1,000 ft	ATC/Tower
			Decision to land	ATC/Tower
			Landing & Rollout	ATC/Tower ATC/Ground Control
			Taxi to gate	ATC/Ground Control Ground Marshaller Driver of Follow Me Jeep
3	Flight Review & Report		Complete Flight Report	Cabin Crew
			Exit Aircraft/ Start Next Flight/Handover to Next Crew	Cabin Crew Next Crew (if aircraft change) Flight Operations Control (If Required)

Specifically, research indicates that Flight Crew collaboration/teamwork with other roles can be understood in relation to a number of core tasks. This includes:

- Flight Crew request information from other operators, in order to execute their tasks
- Flight Crew and other operators agree on specific flight decisions
- Flight Crew provide information to other operators so that they can execute their tasks
- Operators perform tasks, which are an input to Flight Crew task performance (these tasks may be performed prior to Flight Crew performance of the relevant task, or in parallel to Flight Crew performance of other tasks)
- Operators collaborate with Flight Crew as part of the execution of Flight Crew tasks (depending on the situation, the other operator or Flight Crew leads the task)
- Operators provide Flight Crew with information which is relevant to the execution of Flight Crew tasks.

This is facilitated by certain technical tools including ACARS, the crew member's mobile phone, and VHF radio. Thus, the flight team is broader than the cockpit crew, and includes all operation roles that the crew interface with.

Flight Crew Co-ordination

Flight Crew co-ordination takes the form of different formal and informal briefings, as specified in Table 23 below.

Table 23: Flight Crew Communication/Information Sharing Strategies (Study 4)

Direction of Flow & Roles	Communication/Information Sharing Strategies	
	Formal	Informal
Between Flight Crew	Formal briefings – pre flight and top of descent Checklist execution	Informal briefing in transit to aircraft Informal briefings during flight • By talking directly person to person and referring to own experience or understanding of situation • By talking directly person to person and referring to information on computer systems • By talking directly person to person and referring to information on paper tools

Jump-seat observations indicate that Flight Crew continuously communicate with each other with regard to the overall flight situation and the status of flight tasks. This was especially evident when problems arose. For example, in regard to Airline 5 observations, crews continuously communicated about the resolution of the aircraft technical status. Further the crew communicated about routing changes and ATC requirements. However, the situation was slightly different in regard to Airline 2. Serious turbulence was encountered on the third flight. Further, there was a bird strike in the approach phase. In both instances, the Flight Crew did not communicate directly about the status of these events. On landing, the crews alluded to these events. When questioned about this at a later stage, both crew members indicated that they were mutually aware of these problems, and that the situation was easily managed without direct communication.

Flight Crew Co-ordination with Different Roles

Jump-seat observations indicate that Flight Crew continuously communicate with other operational roles, throughout the flight. Before the flight, the crew communicate with Dispatch, Flight Operations Control and the Co-ordinator. In relation to Dispatch and Flight Operations Control, the level of communication varies according to the risk status of the flight. While in the crew room, the crew typically communicate directly with the Dispatcher. If a problem occurs, the crew communicate with Flight Operations Control. This communication is usually mediated via a telephone. Once at the aircraft, the crew are involved in ongoing communications with the Co-ordinator and to lesser extent, with the

Cabin Crew. Flight Crew communicate with the Co-ordinator about the flight status (i.e. if delays, ATC window updates) and about the load status (i.e. passengers, baggage and cargo). During all of the observations, the Co-ordinator arrived in the cockpit either after the Flight Crew landed, or after the Flight Crew boarded the aircraft. Crews then communicated with the Co-ordinator over the ground frequency, and the Co-ordinator appeared a number of times again. A number of times, the Co-ordinator entered the cockpit without disturbing the cockpit crew. On these occasions, the Co-ordinator either deposited paperwork, or took paperwork that the Captain had set aside. Flight Crew communicate with Cabin Crew about the technical status of the cabin (i.e. if defects or not) and passenger boarding. In addition, Flight Crew communicate with Cabin Crew about the status of the doors (i.e. if closed), and the cabin (i.e. if secure) before takeoff. Before flight, the cockpit door was left open and the senior cabin crew member entered the cockpit and waited to talk with the Captain. During flight, the senior cabin crew member used the personal announcement system to communicate with the Captain. Alternatively, the senior used the access code and entered the cockpit, following the Captain's permission. If there is a technical issue, the Flight Crew communicate with Maintenance personnel. In both Airline 2 and 5, maintenance is on request. In regard to Airline 5, Flight Crew communicated with Maintenance twice (i.e. two out of three flights). In regard to Airline 2, Flight Crew interacted with Maintenance twice (i.e. two out of four flights). Flight Crew also communicate with the Fueller about the status of aircraft fuelling. On the whole, the interaction with the Fueller was quite straightforward. The Fueller handed the First Officer the fuel receipt, through the cockpit window. Further, the crew interact with Ground Operations regarding push-back clearances and takeoff clearances.

During flight, Flight Crews primarily communicate with ATC. Flight Crew communicate with ATC to request flight plan changes, to receive flight plan changes, and to confirm or request clearances. Across all observations, ATC interruptions occurred at different points during the initial takeoff briefing, the top of descent briefing and the final approach briefing. On these occasions, the briefing was interrupted, but continued after the ATC communications finished. In regard to the third flight with Airline 5, Flight Crew received three different changes to the takeoff procedure at the runway line-up stage. This was noted by crews during the cruise. During the initial approach phase of the first flight with Airline 5, crew were required to hold, given traffic volume at Madrid airport. It was observed that this is often the case. During de-brief interviews with crews from Airline 5, the Captain remarked that: *"ATC often make requests to reduce speed/hold at certain points and/or speed up at a later point"*. The Captain went on to say that this *"impacts on the stability of the approach"*. During observations with Airline 5, the Spanish controllers spoke mostly in Spanish. As reported by one participant *"non standard language usage (i.e. English), can create problems for other traffic, who need to keep track of ATC communications with other aircraft, to develop a clear*

mental model of the traffic". Traffic problems (i.e. either landing traffic ahead or traffic taking off at the destination airport) can create problems for Flight Crew. In this respect, a First Officer from Airline 5 noted that *"ATC are trying to make the best of the situation, and manage the overall traffic flow. This often necessitates last minute changes to the Flight Plan at late stages in the approach and landing. For crews, this can be quite stressful. Crews might have to re-brief on the flight profile, with very little time".* Sometimes there can be a conflict between ATC navigation requirements and Flight Crew attainment of a stable approach. In this respect a First Officer from Airline 5 stated that: *"ATC often lack an understanding of the specific aircraft performance constraints in relation to the descent speed/profile".*

Flight Crew also communicate with Cabin Crew about the status of the cabin (i.e. if passenger issues), and to inform cabin crew about passenger transit information.

Field research points to the importance of the Flight Operations Duty Manager function during the descent, approach and landing phase. This concerns the management of problems or changes during the approach and landing, from the top of descent until the final approach fix (i.e. in relation to commercial issues around the choice of alternate, passenger transit information and information about services and equipment at destination airport).

Also, during flight, if there is a technical issue with the aircraft, Flight Crew contact Flight Operations Control, who in turn inform Maintenance.

After landing, Crew communicate with Ground Control and Ground Operations. The main communication mediums are person to person, mobile phone, the operations frequency, the ATC frequency and ACARS.

Teamwork & Workflow Management

Cockpit observations suggest that the kick-off and completion of a task depends on (1) the prior or ongoing completion of task outputs from other operational roles (i.e. Dispatch, Co-ordinator, Maintenance, Fueller, Cabin Crew and Flight Operations Control), and (2) the quality of these task outputs. For example, to make the final aircraft weight and balance and performance calculations, Flight Crew require the final aircraft load (i.e. passenger, baggage and cargo weights and distribution). Flight Crew obtain initial passenger figures from the Cabin Crew, and the detailed load information from the Co-ordinator. If there is a delay receiving the final load sheet, Flight Crew will make draft calculations based on Cabin Crew information regarding actual passenger numbers, and provisional load information in the Flight Plan. Flight Crew will then press ahead with other tasks (i.e. briefing, reviewing charts and interaction with Ground Control). Performance calculations are updated, once this information is available. This requires strong task management skills on the part of the crew. In addition, it requires strong communication and co-ordination (1) between the cockpit team and (2) between Flight Crew and other roles.

All participants noted that ongoing task interruptions both on the ground and in the air impact task workflows. Several participants remarked that it is not always possible to complete tasks in accordance with SOPs. For example, on the ground, there are often interruptions from Maintenance, the Co-ordinator, Ground Control, Load Control, Cabin Crew and Flight Operations Control. Equally, during flight, crew are often interrupted by Cabin Crew, ATC and Flight Operations Control. This was validated during flight observations.

Teamwork and Information Sharing

The importance of reliable and current information was emphasized by all participants. Uniformly, participants remarked that having the right information at the right time, is critical to situation assessment and decision making. Conversely, not having the right information or delays getting the information can lead to an incorrect diagnosis of the situation and poor decisions.

At different points in the flight, the performance of certain Flight Crew tasks depends on Flight Crew obtaining information inputs from other operational roles (i.e. Co-ordinator, Maintenance, Flight Operations Control, ATC and Cabin Crew). Consistently, crews reported problems obtaining key operational information from these roles. Crews repeatedly stated that in the current process they are required to pull information from these different roles. Further, it was observed that the late delivery of information makes problems and/or changes more difficult to manage. Moreover, as reported by participants, this can increase both workload and stress. As stated by a First Officer from Airline 5: *"in many cases it is the information situation and not the specific operational issue or change that creates the difficulty*".

Although airline procedures define when the crew communicate with different operational roles and what information is communicated, this is not always followed. Jump-seat observations reveal that much information sharing between the different roles is informal and opportunistic. For example, in the case of Airline 5, technical issues arose in the case of two flights. Flight Crew immediately contacted Maintenance using their mobile phones, as opposed to contacting the Co-ordinator. Having contacted Maintenance and discussed the issues, the Flight Crew then updated the Co-ordinator.

Also, participants noted that they regularly request information updates or initiate communication regarding operational issues. For example, in relation to Airline 2, participants stated that crews always request flight plan updates on multi-sector trips within Norway, as there can be changes to the original Flight Plan due to ATC restrictions. Typically, Flight Crew request updates via ACARS, and then updates are provided to the crew. In relation to Airline 5, it was noted that crews are often the last people to find out about flight delays, aircraft technical issues and ATC problems. As stressed by one participant *"this information is not automatically provided to them"*. Participants remarked that

they continuously chase specific types of information from Dispatch, the Co-ordinator, or from Flight Operations Control. From a crew perspective, it would be better if the process was improved such that this information is automatically sent to Flight Crew.

Operational and Environmental Complexity

Observation and interview feedback suggests that crews encounter a spectrum of both operational and environmental problems on a daily basis. As such, flights are characterized by different levels of operational and environmental complexity. All participants alluded to a range of operational issues which may arise on the day. This includes aircraft technical problems, delayed incoming aircraft, sick crew, delayed crew, passenger delays, lost luggage and/or unaccounted for luggage. Environmental complexity relates to the nature of the weather at the time (i.e. at departure and destination airports, and en route) and the complexity of the routing (terrain/traffic at departure and destination airports and en route). In relation to Airline 5, most flights are conducted in good weather conditions. In poor weather conditions (i.e. fog, rain, snow, storms and wind-shear), the aircraft is configured differently to optimise performance in the specific weather context. In these circumstances, instrument flight procedures are followed and there is increased use of automation. Departure and/or approach procedures at specific airports can be more complex given (1) the local geography (i.e. mountainous terrain), (2) traffic volume and (3) availability/serviceability of airport navigational equipment (i.e. ILS and VOR). Traffic volume in relation to both landing and departing airport traffic can result in late descent clearances, requirements to enter holding patterns, missed approaches and so forth. Further, certain routes can have higher traffic volumes resulting in additional workload due to flight plan changes (i.e. flight level changes and re-routes).

Overall, the different operational and environmental problems experienced by crew, impact on task performance. Specifically, (1) task workflows, (2) time to task, (3) task complexity and (4) task workload varies according to the level of operational and environmental complexity. For example, crew may be required to spend additional time reviewing the aircraft technical status with Maintenance personnel. If technical problems cannot be resolved, an aircraft change is required. Crews must then make an inspection of the new aircraft, thereby increasing their workload and impacting on the time available to complete other tasks. Typically, this leaves the crew with less time for flight briefing and the review of taxi and departure charts. In such circumstances, crew often rush the briefing to maintain the ATC window. Further, the presence of certain issues can generate the requirement for new tasks (i.e. aircraft technical issues requiring co-ordination with Maintenance Engineers and Flight Operations Control and potential aircraft changes).

TEM and CRM strategies are used by crew to manage operational complexity. The crew also follow checklists and brief accordingly. In relation to Airline 5, the crew members used a new TEM checklist at the pre-takeoff stage. In so doing, the crew agreed what the critical threats were and how these might be managed. It is worth noting that the Captain of this flight was involved in CRM training.

Interview and observation feedback suggest that threats arise from a mix of both internal factors (i.e. Flight Crew specific or organisation specific) and external factors (i.e. weather, ATC restrictions and terrain). Some of the threats/issues experienced by the crew result from problems originating in the two other sub-processes (i.e. problems in the production of the Flight Plan, or problems handling safety or other operational feedback about specific flights/airports). This is in addition to a range of internal and external problems that can occur in real-time.

Certain threats are known in advance of the flight (i.e aircraft technical status), while others arise during the course of the operation. In both airlines, the risk status of the operation is reviewed at the dispatch stage. The classification of a flight as safety critical is usually undertaken by the Dispatch Department, in conjunction with Dispatch and/or Flight Operations Control. Typically this occurs shortly before the dispatch of the flight. All participants stressed that both operational and environmental conditions can change shortly before or during the flight. Problems arise either (1) shortly before the flight (i.e. one to two hours prior), or (2) in real-time (e.g. at the briefing stage in the crew room, or in the aircraft turnaround). Problems are managed by Operations Control in co-ordination with the relevant function (i.e. Co-ordinator, Maintenance and Ground Operations) as they arise. Depending on the timeline, Flight Crew may or may not liaise with Dispatch and Operations Control regarding the resolution of problems or proposed changes (i.e. new alternates, new flight levels, fuel changes, route changes, crew changes and aircraft changes).

Tools & Information

Key Tools and Information Resources

Research indicates that Flight Crew use a range of tools and information resources at different points in the operation. The specific use of these tools and information resources varies according to the flight phase or process gate. Nonetheless, several tools and information resources emerged as central. These include a mix of both physical tools and non physical tools.

The Flight Plan is a key tool for Flight Crew. As observed by a First Officer from Airline 2: *"the Flight Plan sets the scene for the flight"*. All parties have access to the Flight Plan (i.e. Flight Crew, ATC and Flight Operations control). As such, the flight plan is the primary

reference point for any flight related negotiations. Across all jump-seat observations, the crew annotated the Flight Plan – recording actual flight parameters (i.e. flight times, fuel consumption and ATC flight levels). In this way, the Flight Plan acts as both a reference point and a record of the flight – consolidating all critical flight information as it changes through the course of the operation.

Jump-seat observations indicate that ACARS is critical insofar as it provides ground air connectivity. This tool is used to obtain relevant operational updates (i.e. interact with Flight Operations Control).

Both jump-seat observations and Flight Crew interviews revealed that crew members use their mobile phones, while on the ground, to obtain real time information from other operational roles. As pointed out by participants, crew use their mobile phone given difficulties contacting either ground personnel or Flight Operations Control, using VHF.

VHF or HF radio is used continuously for communication with ATC. Participants reported many problems in relation to the use of VHF or HF Radio (i.e. access issues, language issues and problems obtaining a common situation picture).

Research indicates that the FMGS/FMC is also critical. During observations, the crew appeared to continuously monitor the navigation display - adjusting the weather and routing scale overlays. In all observations, both PF and PM used different display configurations. This relates to the display of weather and terrain information, and the level of zoom for the routing presentation.

Participants emphasized the utility of checklists from a task management/workload perspective. Specifically, checklists are used to monitor the status of flight tasks for any given flight phase. The use of checklists is also important from a CRM perspective. As stated by a Captain in Airline 5, *"Checklists structure crew communication and ensure that the crew are mutually briefed about the flight context"*.

All participants alluded to the important role of charts, in terms of obtaining specific departure, arrival and approach procedures information. In this respect, participants referred to the SID, STAR and IAP. Two participants stated that they refer to these charts for information concerning minimums and VHF frequencies. Three participants also referred to enroute charts which provide terrain information. One participant reported that *"he usually cross references the out the window picture with these charts to confirm his location"*.

Participants also referred to certain abstract or non physical tools. This includes the following:

- Flight Crew development of a mental picture of the proposed flight
- Flight Crew application of rules of thumb (i.e. weather and impact on flight and ATC issues with traffic ahead and impact on their flight)

- Flight Crew application of TEM/CRM practices
- Formal communication between Flight Crew (i.e. briefings)
- Informal briefings
- Communication between Flight Crew and other roles – specifically Dispatch, Flight Operations Control and ATC
- Flight Crew knowledge of procedures
- Flight Crew reference to prior experience, in identifying a course of action.

Relationship between Task, tools and information

Tools and Information as Task Aids

Firstly, Flight Crew tools and information resources function as task aids. This can be understood in relation to three levels of task aids. Certain tools and information resources provide information which is used as part of task performance. As shown, Pilots obtain task information from a number of different information sources. This includes (1) self, (2) other Pilot, (3) other operational crew, (4) paper tools (i.e. charts, manuals, and checklists), (5) electronic tools and (6) the out the window view. The information provided by the tool or information resource, acts as a task support function, insofar as it is used to make decisions about task actions. Examples of such tools include charts, SOPs, the Flight Management System, communications from ATC, communications from Maintenance, and communications from the Duty Manager. Secondly, tools are used to perform task functions. For example, certain tools are used to change flight levels, to gather information and to send relevant task information to other operators. Thirdly, a number of tools automate task functions (i.e. the aircrafts auto-flight system).

Tools Shape Task Workflows

The nature of the Flight Crew task and specifically task workflows is a function of tool design. In this regard, participants alluded to task constraints which arise as a result of the design of the current flight plan. Currently, the flight plan is updated shortly before the flight and presented in paper format. Certain key information (i.e. aircraft technical status) is either not provided in the flight plan, or the information can be out of date. To this end, Flight Crew must pull information from different operational personnel to determine the latest status of the flight/aircraft.

Tools/Information Shape Task Outcomes

Further, research indicates that insofar as tools and information shape task performance, the quality of tools and information impinges on task outcomes. This in turn has an impact on the overall achievement of the operational goal.

As noted by a Captain from Airline 5: *"If information is unavailable or not current, crews cannot complete their task"*. Specifically, crew must wait for information. As such, crew are continuously tracking the status of this information. This requires additional effort on behalf of the crew – specifically in terms of information monitoring and task management. As revealed in user interviews, this can be stressful for crew. Further, this can impact on the completion of other tasks (i.e. the use of load information for both weight and balance and performance calculations).

If the information provided is incorrect, this has an implication for task outcomes. False information can lead to an invalid situation picture, or an incorrect calculation. Participants noted that the accuracy of information is critically important in relation to takeoff and landing calculations. In this respect, a First Officer from Airline 2 stated that *"they often double check load information to ensure that it is accurate"*.

Task Allocation

Participants stated that Flight Crew are allocated tasks (both technical and non technical) based on two criteria. Firstly, crew are allocated certain tasks based on their rank or grade (i.e. Captain/First Officer distinction and associated authority/command rules). Secondly, crew are allocated tasks based on their specific flight role (i.e. either Pilot Flying or Pilot Monitoring). During the flight planning/briefing phase, crew agree on their specific role for the first and subsequent flight. Typically crews alternate roles on consecutive flights. Overall, the performance of these tasks follows the logic/timeline of the flight operations process and specific SOPs.

On the whole, crew role task assignment was standardized across both Airline 2 and 5. Nonetheless, some variability with regard to the Captain role was identified across Airline 2 and 5. In both airlines, the signoff of the fuel figure is the Captain's responsibility. Nonetheless, the Captain is expected to consult with the First Officer about this. Jump-seat observations with both airlines suggest that both crew members are equally involved in this task. It is worth noting that in both cases, crews were familiar with each other and the First Officers were very experienced. However, this is not always the case. Participants stated that depending on the Captain style, and the relationship/familiarity between the crew, the First Officer may be more or less involved in these tasks. As remarked by a First Officer from Airline 2: *"Sometimes a Captain might dispatch the flight without consulting the First Officer"*. In both airlines the review and signoff of the technical log is the Captain's responsibility. Jump-seat observations suggest that First Officer involvement here varies. In regard to Airline 5, the Captain consulted the First Officer, and the First Officer posed questions to Maintenance Personnel. In regard to Airline two, the Captain was the main person involved. In all cases, the Captain signed off the technical log. Further, in both airlines, the crew

performed the aircraft walk-around on consecutive flights. In Airline 2, participants remarked that this duty is usually shared between both crew members. In Airline 5, participants stated that typically the First Officer performs the aircraft walk-around. In terms of flight observations, crews from both Airline 2 and 5 appeared to alternate this task. In Airline 5, it was noted that the captain performs the landing at certain airports, given the complexity of the approach procedure.

Flight Crew also perform certain tasks based on their role in the flight (e.g. PF or PM). For example, the PF is responsible for aircraft navigation, guidance and control. Equally, the PM is responsible for communicating with ATC and managing weather updates. This PF/PM task allocation is quite complex, in the sense that the performance of certain PF tasks varies according to the rank of the PF (i.e. if First Officer or Captain). As such, the CPT/FO responsibility links to certain PF/PM requirements. For example, if the First Officer is PF, the First Officer may or may not have to do the aircraft walk-around and cockpit checks (usually PM tasks). On certain occasions the CPT (acting in PM role) may do this. In airline two, crews perform taxi based on PF/PM allocation. In Airline 5, the Captain is responsible for aircraft taxi (before takeoff and after landing); irrespective of which crew is PF/PM. If the First Officer is PF, the Captain (acting in the PM role) performs the airport taxi and hands over the controls to the FO on approaching the runway line-up position. The FO (acting in PF role) then makes the takeoff. Further, in Airline 5, if the First officer is PF, the First Officer can land the aircraft but must transfer controls to the CPT during the runway roll-out. This is not required of the FO in Airline 2.

Jump-seat observations reveal that Flight Crew do not always adhere to SOP in regard to PF/PM task allocation. During two jump-seat observations with Airline 2, certain PF tasks (e.g. programming the FMGS) were shared between PF and PM. Participants from both airlines stated that in certain situations, the PF will handover control to PM for a short period (e.g. to make a passenger announcement or to review the flight plan). That said, in both airlines, Flight Crew performed certain tasks according to the PF/PM task allocation. In both airlines aircraft guidance and control tasks were performed by the PF, while communications with ATC were performed by the PM.

Safety Behaviour

Use of procedures

Pilots value procedures from a safety perspective and task performance is quite procedural. Feedback from interviews and observations suggest that crews always perform checklists. It was remarked that the execution of checklists is critical to task management and to broader error management activities. In addition, Pilots follow departure and approach procedures, unless instructed differently by ATC. Overall CRM procedures are followed. However,

specific task procedures in relation to the execution of formal briefings (i.e. the pre-flight briefing and the briefing at the top of descent), are not always followed. This is discussed in more detail in a later section.

That said, task performance does not always follow the specific procedure as detailed in airline SOPs. Often, there is insufficient time to execute procedures as defined in SOPs. In such instances, technical procedures are often prioritized over non technical procedures. As such, certain non technical procedures may be skipped. There is a task management dimension to this; crews make decisions as to which tasks to priortise if workload is high, or in time critical situations.

Each flight presents different challenges. Periodically, situations are indeterminate and it is not always possible, or advisable to follow procedures. In managing the particular flight context (and associated levels of complexity), crew draw upon their prior experience and expertise in relation to identifying a suitable course of action. Often, this necessitates that Flight Crew optimise airline SOP, following an assessment of the situation.

Pilots can also be complacent about the requirement to follow procedures. In this regard, procedures are either skipped, and/or not followed strictly.

Participants also noted that procedures can be unknowingly skipped, or forgotten, due to crew fatigue.

Use of CRM/TEM in the Operation

All participants acknowledged the utility and relevance of CRM training. A number of participants reported that the concepts explored in CRM training strongly influence their mental models of what it means to be safe. These participants stated that they conceptualize flight safety in terms of two sets of states. This includes aircraft states and crew states. In terms of aircraft states, the aircraft must be in the appropriate configuration for the given flight phase. In relation to crew states, the crew must be well briefed, situationally aware and well co-ordinated.

Flight Crew use both CRM and TEM concepts in routine operations. This relates to specific communication and TEM practices deployed in crew briefings. Across all interviews, crews noted the importance of positive relations both between Flight Crew and between Flight Crew and Cabin Crew. As pointed out by a First Officer from Airline 2: *"If you are rostered to fly with the same crew for three days, then it is essential to establish a good working relationship – or at a minimum to establish an appropriate way of working together"*. In this regard, all participants indicated that safety is enhanced when crew work as a team and apply CRM skills. Two participants noted that to properly task share, Flight Crew need to work as a team and be aware of their co-pilots needs. As stated by a Captain from Airline Two pointed out: *"If you believe in team – you empathise with your team-mate - having team*

goals allows crews to task share more easily". This participant observed that in general, older First Officers perform tasks swiftly and usually without errors. Conversely, new First Officers perform tasks more slowly and often make errors. In this way, it is easier for a Captain to fly with an experienced First Officer. On the other hand, it is easier for a First Officer to fly with a senior Captain. Thus, the same Captain observed: *"It is important that the Captain provides a complete briefing to new First Officers at the dispatch stage. Further, new First Officers may require some assistance at the cockpit preparation stage. Here there are many things for the First Officer to do and little time available".*

Four participants stated that CRM training highlights the importance of situation awareness. One participant pointed to the link between situation awareness and other CRM behaviours. *"Good team work requires strong communication and co-ordination – if this is good, then this will result in common situation awareness and improved decision making".* Participants reported that they do not always have full situation awareness and errors can and will happen. Uniformly, it was stated that the main thing is to manage errors, and in so doing, to avoid undesirable aircraft states. According to three participants, TEM training encourages crews to monitor and evaluate their own performance, along with that of their co-pilot. One participant reported that that *"By monitoring flight threats and errors and the management of these, they are situationally aware"*. For this participant, *"TEM is linked to situation awareness or they are different aspects of the same thing".*

All participants suggested that it is more likely that they will form a correct situation picture and make the right decisions, if they have the right information to hand. Nevertheless, four participants reported that decisions are often made without full information/complete situation picture, and these decision are not necessarily bad ones. In this respect, all participants emphasized the importance of having 'situation awareness', or 'information awareness'. Further, all participants referred to 'information awareness' – linking information awareness to situation awareness. In response to questions about how they understood 'situation awareness', participants provided a range of definitions or concepts. According to one participant, situation awareness is *"understanding and being aware of the specific factors that relate to your flight – the threats to manage".* Another participant described it as *"the capacity of the pilot to consider the risks involved in the operation and the issues that affect the security of the aircraft".* As reported by another participant, *"situation awareness refers to obtaining and monitoring all information related to my flight".*

Pre Flight, Flight Planning & Briefing Task

As highlighted in interviews with participants from both Airline 2 and Airline 5, the pre flight, briefing is essential in terms of supporting teamwork and in particular, team situation assessment.

User interview feedback suggests that a complete briefing is more the exception than the rule. Often, a minimal briefing is performed. For example, crew noted that in many cases the turnaround time is reduced given aircraft changes, crew changes or delays. This has an impact on the briefing. In such instances, the briefing is rushed and/or certain steps are omitted. Typically, the crew will focus on delivering key operational outputs such as agreeing the fuel load and signing off the Flight Plan. In this way, the briefing does not always follow best practice guidelines in briefing as relayed in CRM training. In these situations, key CRM outputs such as the joint assessment of flight information and the establishment of team concepts are in jeopardy.

Across the interviews, participants pointed to the relationship between the quality of information provided to the crew and the quality of the briefing. As reported by participants, there are a number of key situation assessment milestones in the process, necessitating crew gathering, integrating and assessing the latest flight information. According to participants, the most important of these is at the dispatch phase. At the pre-flight stage, the crew gather key operational and safety information from team agents involved in the Active Flight Operations Process and other processes that interface with this process. Here the main threat is crew not obtaining the necessary information or the late delivery of information. As reported by participants, this can result in crew forming an inappropriate or inadequate assessment of the situation. This in turn has an impact on the quality of Flight Crew decisions such as the fuel decision and the signoff of the flight routing.

Many of the First Officer participants reported that the attitude of the Captain can often influence the style of the briefing and overall nature of crew teamwork. Participants stated that they tend to read the body language and style of their Captain, before establishing a way of working. One participant described how it is possible to *"read from way the Captain performs the flight dispatch, or from the way he/she sits', what the relationship will be like, and what the best way to interact with him/her is"*. This participant noted that he alters his strategy, if he thinks the Captain is more relaxed or more serious. Further, it was noted that the briefing strategy is altered, if the crew are familiar with each other. In general, these assertions were borne out in jump-seat observations with both Airline 2 and Airline 5 and the observations of crew briefing at the crew room in Airline 2. Overall, nine pre-flight, flight planning and briefing sessions were observed. In the case of Airline 2, there was one set of crew for the first three flights, and a crew change (change of First Officer), for the last flight. Two briefings were performed in the crew room – one of which was an outstation, while two

were performed in the cockpit (i.e. turnaround briefings). In terms of the crew room observations, this involved two different sets of crews. In relation to Airline 5, there was one set of crew for the three flights. Two briefings were conducted in the crew room – one of which was an outstation, while one was conducted in the cockpit. In terms of the jump-seat observations, the crew members knew each other and were familiar with the routes to be flown. This may have impacted on the style of the briefing. However, in relation to crew room observations, the researcher did not elucidate whether the crew members knew each other, or whether they were familiar with the route/airports. This was an opportunistic observation.

The briefings conducted in the turnaround were shorter than those conducted at the crew station. During de-briefing sessions, participants noted that there is less time to perform the briefing in the turnaround – given reductions in turnaround times. In all jump-seat flights, there were many operational issues/changes to be managed. Further, the information picture related to these issues/changes kept changing. In all cases, the Flight Crew interacted with the Co-ordinator to obtain the latest information. In relation to turnaround, the crew obtained information updates from ACARS. Moreover, the crew used their mobile phones to elicit information concerning operational updates. This involved contact with Maintenance, Dispatch and Flight Operations Control. In subsequent de-briefing observations, the crew reported that the existing Flight Plan does not provide the latest information about operational changes or issues. Further, participants reported that the Flight Plan provides limited information about the technical status of the aircraft.

Jump-seat observations with Airline 5 demonstrate that the crew use explicit TEM strategies as part of the flight. In all three flights, there was a detailed conversation between the crew as to existing and potential flight threats, and associated TEM strategies. As part of the briefing, the Captain alluded to both existing and potential flight threats and relevant mitigation strategies. Further, the Captain invited the First Officer to comment on this. However, it should be noted that the respective Captain is a CRM trainer and the explicit reference to CRM/TEM behaviours, may not be representative of the broader crew population. Further, in all three flights, the Captain introduced the briefing checklist advanced by this airline. Again, this Captain was involved in development of this tool, and this may not reflect broader operational practice. In both jump-seat and crew room observations of Flight Crew briefing at Airline 2, the crew discussed specific weather threats. However, a broader TEM briefing was not conducted.

On duty and off duty

Across all sessions, participants noted that Flight Crew task requirements and associated information needs vary according to their duty/roster status.

Flight Crew have two on-duty modes. Here, participants distinguished days where they are flying (i.e. on duty/flying mode) and training days. In relation to on duty/flying mode, Flight Crew task requirements mostly link to the functional logic of the Active Flight Operations process. However, reporting tasks link to the Safety/Quality/Improvement process. Participants also distinguished the point in the operational process/timeline (i.e. pre-flight, flight execution, post flight), and their location (i.e. crew room office or aircraft).

The crew perform several mandatory tasks while on duty but not flying. Primarily this relates to the attendance of various training sessions such as CRM training, classroom training, and simulator training. Thus, these tasks pertain to the safety/quality/improvement process.

While off duty, the crew perform several optional safety management tasks. Optional tasks include (1) the review of training information, (2) voluntary reporting, (3) the review of performance feedback information (i.e. flight specific feedback information, and fleet specific safety case studies, (4) the review of safety actions linked to Flight Crew reports and (5) flight preparation/briefing (i.e. future flights). With the exception of flight preparation, these tasks mostly link to the Safety/Quality/Improvement process. However, Flight Crew advance briefing activities pertains to the Active Flight Operations process. In relation to being 'off duty', participants distinguished different points in their schedule and their related location. For example, participants differentiated being on holidays, being in the crew hotel after a full day's work, being at home a few hours before the first flight of the day, and finishing a pairing and returning home after this.

Task Management

All participants identified task management as an ongoing task throughout the operation. As reported by participants, the transport of passengers from one location to the next, involves the management of tasks in relation to the broader operational process. Flight Crew must ensure that task workflows correspond to the functional requirements of the process, at specific process gates. This necessitates the ongoing monitoring/tracking of both individual and team performance, in relation to the current and future situation. Task management is facilitated by good communication and co-ordination between the Captain and First Officer, and by crew experience/expertise. Further, it is supported by the use of checklists. Participants emphasized that crew task management is negatively impacted by fatigue and/or stress. As observed by several participants, task management problems mostly relate to broader process dependencies. This includes difficulties obtaining information about the status of tasks completed by other operational agents, or contingencies relating to obtaining information inputs from other operational agents.

5. RESULTS: PHASE 2

Pre flight, flight planning and briefing task

Task Significance

All six participants commented on the importance of this task from both an operational and a safety perspective. From an operational perspective, participants alluded to three possible outcomes:

- Signoff flight plan (i.e. as is)
- Signoff flight plan following the actioning of specific changes (i.e. changes to routing/alternates and request for additional fuel)
- The flight plan is not signed off (i.e. cannot go given weather issues, aircraft issues and/or crew issues).

According to participants, the Flight Crew frequently request changes to the Flight Plan (i.e. outcome two). This has an impact on the operation (i.e. involvement of Dispatch/FOC in relation to routing changes and updates to Fueller in relation to fuel load). Participants reported that the third outcome is relatively infrequent. If this occurs, this as a global impact on the operation – in terms of changes to the flight schedule, flight delays and/or flight cancellations.

Participants also alluded to the importance of this task from a human factors perspective. Here, participants reported three overall human factors outputs of the pre-flight, flight planning and briefing task. This includes: the establishment of the team concept, crew situation awareness and workload management.

CRM objectives underscore the performance of the pre-flight, flight planning and briefing task. Although the explicit objective of this task is to brief on the flight plan so that the fuel figure and routing can be signed off (i.e. operational objective), the underlying objective is to cement team concepts and facilitate joint situation assessment and decision making. As stated by a Captain from Airline 5, *"A good quality briefing ensures that the crew are aware of all risks and equipped to manage these, if they arise later in the operation"*. Rushed briefings and/or poor quality briefings adversely impact on the crew's understanding and assessment of flight information, the identification of threats and the identification of TEM strategies to mitigate the impact of these threats. Further, rushed briefings and/or poor quality briefings adversely impact on team formation. As noted by a First Officer from Airline 5: *"Team concepts established at this early point influence the overall quality of these other briefings"*. In explaining this, the First Officer noted that the crew are involved in a range of formal briefings including the briefing at the top of descent, and specific flight briefings linked

to the execution of checklists at different flight phases. Also, the crew communicate informally throughout the flight. Thus, as stated by the same First Officer: *"The nature and tone of this first briefing dictates the nature and tone of these other briefings"*. In addition, as reported by all participants, implicit in these objectives (i.e. supporting teamwork and crew situation awareness), is a further objective/requirement – namely, to support workload management. All participants stated that the quality of this task has an impact on the quality of Flight Crew task activity more generally (i.e. subsequent tasks). This includes tasks associated with the specific process gate (i.e. fuel decision and flight plan signoff), tasks associated with other process gates in that process phase (i.e. the briefing at the runway line-up) and tasks associated with process phases (i.e. takeoff, the briefing at the top of descent and approach and landing). As reported by a First Officer from Airline 5: *"If the crew are well briefed at this early stage, then it is more likely that they will be able to manage the increase in workload associated with changes to the flight plan"*.

Human Factors Dimensions of Task & Procedural Drift

Participants highlighted several human factors dimensions pertaining to the status of the crew and crew relations which impact on the crew's disposition to perform a briefing, and/or their perception of the requirement to brief. This includes the following: (1) the crew may be meeting for the first time, (2) the crew may have different training and experience backgrounds, (3) one or both of the crew members may not be open to CRM concepts/briefing, (4) the crew may be fatigued, (5) one of the crew members may be returning to work, after a period of sick leave, (6) the crew may or may not be familiar with the route (i.e. they may not have flown it before) and (7) one of the crew members may have minimal experience flying the specific aircraft type (i.e. just joined the fleet).

Crew complacency in relation to the execution of the pre-flight briefing procedure is a real issue. Interview feedback suggests that briefings frequently do not follow SOPs and in particular best practice in briefing as outlined in CRM training. Certain steps are skipped and/or the briefing happens at a later point in the process. A more casual approach is adopted, if the crew know each other and/or have flown together before. Often the crew will not perform a detailed review of the Flight Plan or departure or approach procedures, if they are familiar with the route and/or the particular airport. Further, weather conditions can impact on crew behaviour. Participants noted that their approach to flight planning and briefing very much depends on the weather on the day. As stated by one Captain: *"If the weather is bad you are less relaxed"*. All participants remarked that they make a mental note of the weather a few hours before flight or the day before (i.e. if at home). As such, they come to work, with a level of preparedness/expectation about the forthcoming flight. If weather conditions are good, crews may perform a minimal briefing. However, if weather conditions are bad, the crew will perform a full briefing irrespective of their familiarity with the route or the airport.

Briefing Contexts

Participants noted that the First Officer often checks-in early and reviews flight information, so that he/she is briefed before meeting the Captain. Typically the briefing is executed in the crew room or the cockpit. However, crew often brief – both formally and informally – on the way to the aircraft. As such, the briefing might start in the crew room and finish in the cockpit. All participants observed that they often conduct some form of briefing for special flights from home a day or two before the flight. It was noted that special flights include flights to Africa, Israel and Russia. Participants noted that they routinely perform an initial flight briefing from home/or from a crew hotel in advance of the flight. Further, during operations and specifically low workflow periods (i.e. cruise), Flight Crew often plan for the next flight. In this respect, participants distinguished briefing/planning for the current flight, briefing/planning for the next flight, and briefing/planning for future flights.

Dispatch Process and Flight Context

The nature of the pre-flight planning and briefing task varies according to the type of flight and the risk status of the operation.

As reported by three participants from Airline 5, the dispatch process for short and long range flights varies. The dispatch process is longer for long range flights. In this case, the crew interact directly with the Dispatcher. Further, one participant stated that receiving the latest information updates for long haul is more critical. These flights are longer (i.e. eight to twelve hours) and many things can change in that time. This includes weather, the status of the runway at the destination airport and the status of the navigation equipment at the airport.

For routine flights, this involves the joint review and assessment of a range of flight information by the cockpit team and/or Dispatch personnel. As noted by participants, depending on the airline process, information is presented in paper or electronic format. In the case of Airline 5, information is presented in paper format. In non routine/high risk circumstances, the cockpit team review flight decisions (i.e. fuel load, choice of alternate and routing) with Dispatch and/or Flight Operations Control. In both cases, crew members develop a mental picture of the forthcoming flight, jointly assess potential flight threats and agree on a course of action. In relation to the latter, this includes agreeing on specific threat/error management strategies.

Task Workflow

The pre-flight, flight planning and briefing task commences after the crew check-in (i.e. if in the crew room), and/or at the start of next flight (i.e. if in the cockpit during the aircraft turnaround). Specifically, procedures necessitates that both crew members are present for the task to commence.

All participants highlighted the differences between briefing in the crew room and at the aircraft (if in a turnaround). Three participants noted that this process is managed in a variety of ways by different airlines. It was observed that certain airlines provide crew with flight plan information for all flights at their first flight, and then update crew with the latest information as required. Alternatively, crew receive flight plan information on a piecemeal basis. The latter example applies to Airline 5. In this respect, participants noted frequent delays obtaining flight plan information in the turnaround.

Overall, the Captain leads the briefing. However, given CRM procedures, decision making (i.e. fuel decision and signoff of route) follows the agreement of both the Captain and the First officer. A summary of the briefing workflow is provided in Figure 2 below.

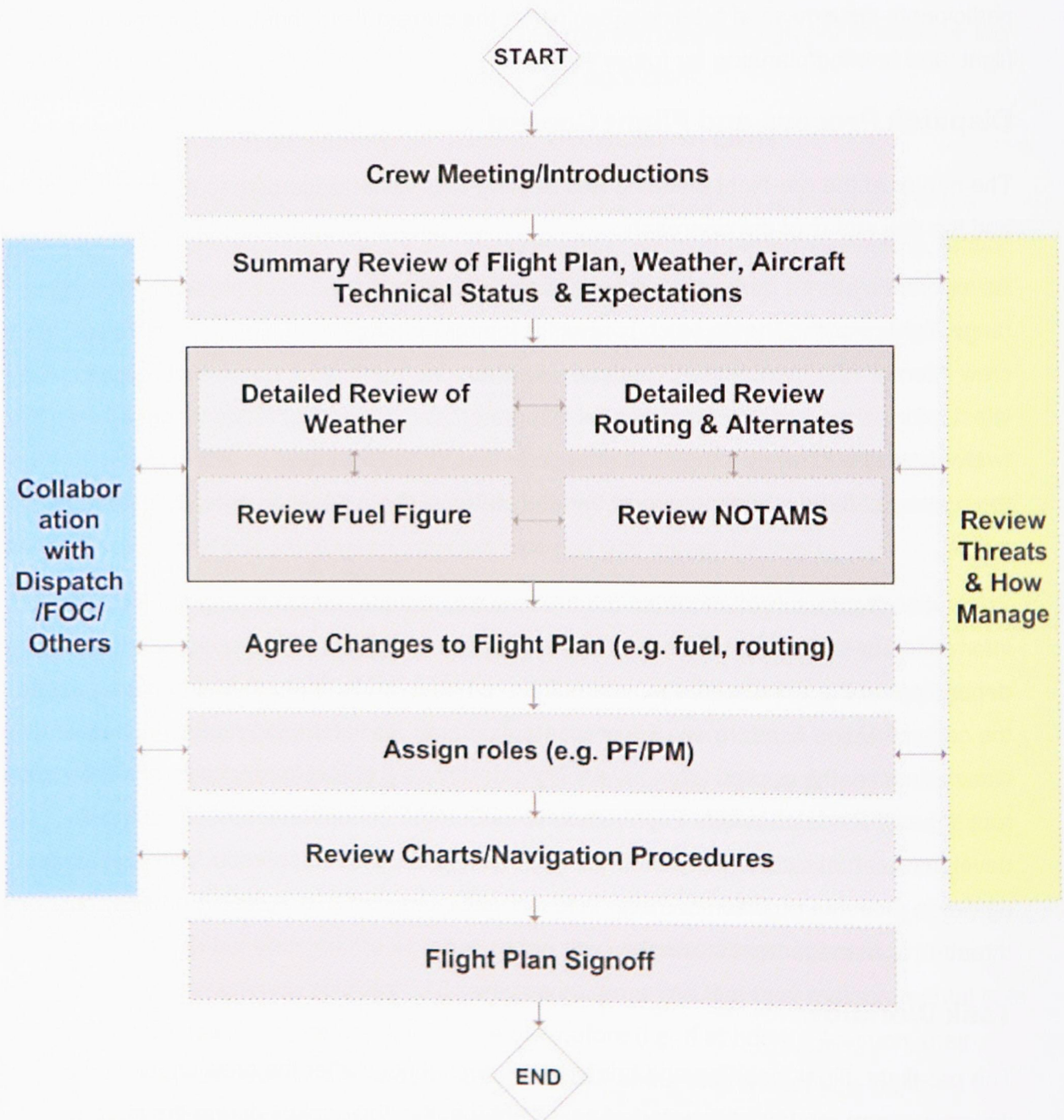

Figure 2: Pre-flight, Flight Planning & Briefing Task, Task Workflow (Study 4)

The workflow is as follows. First, the crew meet. If the crew do not know each other, there may or may not be preliminary introductions. Following this, there is a summary review of the Flight Plan, weather, aircraft technical status and crew expectations. If the weather is bad, then the flight is likely to be more difficult. Further, it there are aircraft technical issues at this stage, then the crew need to prepare for an aircraft change. The official briefing then commences. As part of this there is a more detailed review of flight information. If the flight is a high risk flight, crew review the Flight Plan with both Dispatch and/or Flight Operations Control. In this case, Dispatch and/or Flight Operations Control are responsible for key flight decisions (i.e. aircraft/crew changes, re routes taking into account weather and/or commercial issues, flight cancellations). The review of information includes weather information, routing and fuel information. The crew then review relevant NOTAMS information and brief on any relevant issues pertaining to these. Fuel requirements are then discussed. Depending on the situation, the crew will spend more or less time, reviewing the fuel figure recommended by Dispatch. Pending agreement between both crew members, a fuel decision is reached. The crew will decide to take the recommended fuel and/or will request additional fuel. The decision to go with the recommended fuel figure (i.e. fuel load proposed by Dispatch), or to take additional fuel, can be controversial. As reported by participants, this decision often reflects a belief on the part of crew that this provides an additional safety buffer, should problems be encountered. If the weather is bad, the crew order additional fuel as a matter of course. It was also noted that given changes to the airline's fuel policy, Flight Crew are less likely to order additional fuel, unless they feel it is really required. Four of the six participants interviewed stated that they always add additional fuel as a matter of course. These participants reported that they do not trust the fuel figures provided by Dispatch – specifically they do not trust that sufficient contingency fuel has been factored into the recommended fuel calculation. The two other participants noted that that fuel calculation takes into account a range of contingencies and the context on the day (e.g. latest weather). As such, the addition of extra fuel is not necessary. Further, two participants reported that the flight situation may change after Dispatch has completed the Flight Plan. These participants stated that the aircraft may not be able to fly at the specific altitudes indicated in the Flight Plan, given aircraft technical issues (i.e. MEL constraints), and/or ATC constraints. As such, more fuel may be required to take into account potential flight level changes. Changes to the Flight Plan (i.e. fuel load, routing and alternates) are then agreed. Crew roles are then assigned. If time permits, there is a review of departure and approach procedures. At this time, the Captain will draw the First Officers attention to any special issues related to either the departure and/or the approach, if required. Again, if time allows, the crew may review specific charts information (i.e. SIDs, IAP and STARs). The flight plan is then signed off. The review of threats and how they will be managed is implicit in all of this. Further, each of these tasks involves collaboration with other roles.

TEM Dimensions of Task

Participants reported that the practice of TEM behaviours is a key step in the briefing process. As part of the briefing, the crew review existing and potential flight risks. Participants noted that flight threats are grouped into three overall categories - crew, aircraft and environment. As such, crews make an overall assessment of the situation in each of these categories. This involves gathering information relevant to each of these categories. Thus, crew awareness/understanding of the evolving flight situation depends on (1) the availability, currency and accuracy of information available to them, (2) their understanding of this information in relation to current and future aircraft states and (3) workload/time to task (e.g. having sufficient time to perform the above).

As stated by a First Officer from Airline 5, *"The crew assess the situation in relation to their mental model of what counts as a good or bad situation"*. Overall, a good situation is characterized as one in which there are few, if any, flight threats facing crew. Further, in situations where there are threats, these are not serious in nature. Conversely, a bad situation, is one in which there are one or more serious threats facing crew. Most flights fall between these two extremes. As reported *"most flights involve a number of low or medium level threats"*. In this sense, the flight situation cannot be classified as either good or bad. Rather, it is 'in between'. In explaining this, a number of characteristics of a good situation were highlighted. Broadly, this links to the assessment of the flight situation in relation to the three threat categories as outlined above. In relation to environment, characteristics include, the weather is good, the terrain is not complex and air traffic is flowing (i.e. not congested). In relation to the aircraft, characteristics include: the aircraft is on course (taking into account the latest updates to the Flight Plan), fuel levels are appropriate, and the technical aircraft status of the aircraft is acceptable. In relation to crew, characteristics include, the crew are alert (i.e. not fatigued), the crew are well co-ordinated and working as a team, the crew are appropriately briefed, the crew have a common view of the situation, the crew have all information necessary to perform flight tasks, the crew are performing tasks in accordance with SOPs (or in accordance with what is best given an assessment of the particular situation) and other relevant roles are performing tasks as required (i.e. ATC, Dispatch, Maintenance).

Interview feedback suggests that the main concern of Flight Crew is to transport their passengers safely and efficiently from the departure location to the destination location. If this is not possible with the current Flight Plan, the Captain will request relevant changes (i.e. fuel, routing, alternates and flight level). This decision is usually linked to poor weather or aircraft technical issues. The dispatch process requires Flight Crew to contact Dispatch if they want to request additional fuel, or request different alternates or change flight levels. Further, it the weather is very bad and the crew think that it might be better to delay or cancel the flight they are required to inform Flight Operations Control and agree a course of action.

In addition, if there are technical issues with the aircraft, Flight Crew liaise with Maintenance, Flight Operations Control and the Co-ordinator regarding aircraft changes. In certain cases, such as extreme weather conditions (i.e. thunderstorms and heavy fog), Flight Operations Control may have made a go/no go decision before the Flight Crew check-in. As such, Flight Operations Control decisions are communicated to Flight Crew once they check-in.

Tools and Information

Pilots use a range of tools and information resources to gather information. This includes the Flight Plan, ACARS, and VHF Radio. Further, the crew interact with a range of human agents, to gather information (i.e. the Co-ordinator, Dispatch and Flight Operations control). In general, interview feedback suggests that certain information is critical. This includes information relating to weather, flight routing (including flight levels), fuel, aircraft type and technical status, latest operational status/information (including changes) and NOTAMS. Specific findings in relation to tools and information are outlined in more detail below.

Task Barriers

Participants noted several factors which impact on the quality of the briefing. Firstly, often there is little time to perform the briefing. As shown, reductions in aircraft turnaround times have resulted in less time for the crew to perform the briefing. There may have been an unexpected aircraft or crew change, leaving minimal time for the briefing. Frequently, task performance is interrupted, impacting on crew workflows. For example, task interruptions arising from updates from the Co-ordinator (i.e. load sheet) and/or ATC (i.e. slot updates), impact on crew workflows. As such, the briefing is stopped and then resumed. Certain interruptions require that the crew focus on a different task temporarily, before resuming the briefing task. This is especially the case for briefings performed in the aircraft turnaround/at the cockpit. During this review, the crew often receive operational updates from Dispatch. This can involve changes to the flight plan slot times, aircraft changes, re-routes, passenger/load updates, and updates regarding the technical status of the aircraft. In certain cases, this may require that crew re-brief on certain flight issues. Also, sudden weather changes, aircraft changes, crew changes, and or departure procedure changes, impact on crew workflows. Critically, this necessitates re-briefing. Poor teamwork (i.e. lack of common ground and resistance to teamwork) impacts on crew briefing. Crew resistance to CRM concepts (and specifically the attitude of the Captain), can cause problems. It was noted that information quality, currency and availability impacts on crew briefing. Difficulties accessing information, poor quality information, late information, out of date information and gaps in information, can impact negatively on the briefing. Lastly, the broader organisational culture, and specific safety culture impacts on crew attitudes to briefing.

Task Facilitators

Participants also pointed to certain task facilitators. Fast and timely access to clear, accurate and current information facilitates briefing. This includes the latest updates from Dispatch and the Co-ordinator concerning ATC windows, the health status of aircraft and loading issues. Further, the provision of detailed information pertaining to the flight/aircraft situation is also useful. In addition, problem solving/information sharing with Dispatch and/or Flight Operations Control, regarding potential flight threats, and how best to mange them is also useful.

Problems with Existing Briefing Package & Requirements for Improved Tools

Much of the information which Pilots review at the pre-flight, flight planning and briefing stage, is provided in paper format (i.e. Flight Plan, charts, weather information and NOTAMS). Participants reported several information access and presentation issues linked to the paper format of this information. It was suggested that these might be ameliorated by the introduction of an electronic Dispatch process and/or the use of EFBs.

Three participants remarked that they regularly have difficulty ascertaining the currency of the Flight Plan. Given the dynamic nature of both the flight and the operational situation, the information picture can change. Having information time/date stamped is therefore important.

Participants stated that they have little time to review all information relevant to the flight. As such, critical information should be highlighted so that their attention is drawn to it.

It was suggested that the Flight Plan should provide real-time information about the status of the operation and any relevant operational updates and/or changes. Currently, the crew spend much time trying to access the latest operational updates from different operational roles. Much information is obtained indirectly via the Co-ordinator and or Flight Operations Duty Manager. This relates to information about the technical status of the aircraft, the status of crew (i.e. if checked in or not, if delayed, mode of transport), the status of passengers (i.e. if passengers delayed in transits), and location and status of the aircraft. It was noted that this information is in the system (i.e. known by other people, represented on tools used by other roles), but is not directly available to them, and/or is difficult to access.

All participants indicated that they would welcome flight specific threats information, linking to broader airline SMS processes. Consistent with the design of the briefing and reporting tools recently developed by the airline, participants noted that threats information might be grouped into three types; namely aircraft, crew and environment. Participants also stated that threats information might include some instruction as to best practices for managing

those threats. Best practice briefing instructions might be generated from existing crew reports information and safety case studies.

It was observed that certain information relevant to the flight operation is not in the system, but is 'out there' or 'known'. This relates to information that is in the heads of Pilots, and as such, not directly accessible to other operators. According to participants, this 'expertise' or 'local knowledge' relates to a variety of aspects of the operation. For example, the operating characteristics of a particular aircraft and/or problems specific to an airport. Two participants suggested that this information should be gathered and harnessed from an operational perspective. That is, it should be made available to crews at the pre flight stage (i.e. if flying a specific aircraft or if flying to a particular airport).

All participants observed that they receive sufficient weather information, albeit sometimes this is not up to date.

Participants noted that although the Flight Plan provides specific routing information, actual flight threats relating to routing and associated terrain are not flagged to crew. It was noted that the provision of this information would bolster flight safety.

Currently, the Flight Plan fails to provide information regarding crew factors to be considered in flight. As stated by a Captain from Airline 5: *"The crew are expected to identify and review relevant crew issues at the briefing - however this rarely happens"*. Specifically, it was noted that crew do not always admit to being fatigued or stressed, due to workload and/or personal issues. As such, participants suggested that the Flight Plan might provide information concerning specific crew threats to be managed. A number of participants referred to new Internet developments related to social networking. It was suggested that new airline information portals might feature pictures of crew members, to foster a sense of team and promote social connections. Further, it was suggested that the future Flight Plan might feature pictures of crew members to support the immediate and/or easy identification of team members in the crew room.

All participants mentioned that they would benefit from receiving the latest information regarding the aircraft technical status and location. Participants stated that the existing Flight Plan provides insufficient information relating to the technical status of the aircraft. Uniformly, participants stated that they often do not know what the status of the aircraft is (i.e. if it has landed, or in taxi, and what gate it will be at), and what the technical status of the aircraft is. It was noted that this information is available in advance to Maintenance but not to Flight Crew. One participant observed that the existing Flight Plan was recently updated to include information about the status of the aircraft - but this information isn't always available. Further, all participants stated that they usually discover that there are aircraft technical problems once at aircraft, and not before. Participants also noted, that if there are deferred defects, they need to know what the history of these defects is (i.e. if the defect was closed

before and recurred). A number of participants remarked that this information was previously available to crews, but was withdrawn a few years ago. Interestingly, all participants stated that this information is necessary from a Flight Crew perspective (i.e. if the defect is recurring repeatedly, then they might be more concerned). However, participants indicated that the Maintenance Department would disagree with this. Participants commented that if they feel there is an issue with the aircraft, then they will ask for this information anyway. As stated by a First Officer: *"This is just delaying an inevitable process"*.

All participants noted that they would like the fuel calculation to be made more explicit. Further, three participants noted that they would like trending information related to fuel consumption. Further, five participants noted that they would like to get a high level overview of the latest NOTAMS.

Further, all participants observed that the visual layout of certain information is poorly designed. In this regard, participants consistently referred to the design of NOTAMS information. Participants remarked that the layout of the NOTAMS document makes it difficult to grasp new or important NOTAM information at a glance. As noted by several participants, crew must review NOTAMS piecemeal, often necessitating the review of a number of pages of information.

Participants also suggested that operational updates and notifications might be presented in similar terms to email. As reported by many participants, the use of email is now commonplace (both in terms of work and social dimensions). All participants suggested that in an ideal world, they would be able to communicate and share information with different operational or management roles as and when they need to. When questioned about how real-time communication with other operational roles might work, participants suggested that it might function like email, or similar to the messaging on the ACARS system. Three participants remarked on the limits of the ACARS system in terms of the depth of information communicated and the format of this information. That said, participants stated that in relation to critical communications, they would prefer to communicate with the relevant person directly (i.e. by telephone), as opposed to using an electronic messaging application. In this respect, participants alluded to the immediacy and directness of telephone communication.

Participants reported that they would like to obtain advance information about future flights to support the flight planning/briefing process. Two participants noted that that they periodically review operational information (i.e. SID, STARs and relevant airport and aircraft bulletins), to prepare for upcoming flights. Ideally, this information might be available remotely.

Three participants noted that it is often difficult to get information about the specific location they are flying to and/or relevant logistics information (i.e. pick up times).

New Airline Tools

Crew Website

Participants highlighted the importance of the crew website, in terms of providing key information to Flight Crew. Specifically, the crew website provides information about SOPs, the latest safety information, and information about performance trends. Further, participants remarked that this website provides crew with advance flight information (i.e. twenty fours hours in advance). As part of this, crew members can view the crew manifest – facilitating the recognition of fellow crew members at the crew briefing.

CRM Briefing Tool

Mostly, participants were unaware of the flight planning/briefing guide developed by the CRM training department. This was identified in earlier research with Airline 5. However, all participants reported that they were familiar with the contents of this briefing guide; briefing procedures had been reviewed in CRM training classes. Participants felt that this is a useful tool, inasmuch as it states and/or reminds crew of what they know from training but do not always put into practice. Participants responded favourably to the concept of obtaining a customised briefing instruction linked to the particular flight context, in electronic format in the crew room and/or in the aircraft turnaround. As stated by a Captain from Airline 5: *"this is something that good Captain's normally do informally".*

Threat & Error Management (TEM) Tool

Only three participants were familiar with the new tool developed by the CRM department for recording information relating to flight threats and the management of these. These participants encountered the tool in recent CRM training sessions and/or were briefed about the tool through informal conversations with Safety colleagues. These participants remarked that the tool would prove useful in terms of fostering crew team work – specifically in relation to the joint assessment of flight threats and identification of threat management strategies. When asked about the emphasis on the three flight phases (i.e. pre flight, cruise and top of descent), participants remarked that crew briefing at these flight phases is most critical. Further, participants remarked that the classification of flight threats into three types – namely aircraft, crew and environment - is intuitive.

In the case of those participants unfamiliar with the tool, the researcher described the nature of the tool and how it might be used. Participants noted that the proposed flight phases were appropriate insofar as these phases were most critical from a briefing perspective. All participants stated that the high level classification of risks/threats into three types (i.e. aircraft, crew and environment) matched their mental model of flight threats. Interestingly, three participants stated that they routinely review flight threats in this way. However, these

participants stated that the performance of specific TEM reviews is often hampered by the extra workload and/or stress generated by persistent operational problems. These participants stated that it would be useful to have a tool which externalizes what is in their heads. As pointed out by one participant, this tool *'functions as a memory aid'*. In particular, it was noted that this would support crew briefings. That said, participants remarked that they would not always have sufficient time to record information about flight threats and related management strategies. Two participants suggested that this made sense as a training tool, but not as an operational tool, given the time required to manually record all threats and errors.

The researcher then discussed proposals related to a future electronic version of this tool, linked to the Flight Plan. Specifically, the researcher elicited feedback about the possibility of pre-populating flight threat information in an electronic Flight Plan. Such a tool might be available both in advance of the flight and in real-time at different points in the operation. It was suggested that this might be available either on a work station in the crew room and/or on an EFB in the aircraft. Participants responded favourably to this. In addition, participants suggested that the tool might allow them to record information relating to flight threats identified by the crew, in addition to what might be automatically generated in the Flight Plan. As observed by a First Officer from Airline 5: *"This would encourage high involvement"*.

6. DISCUSSION

Overall Model of Flight Crew Task

Flight Crew task performance can be considered in relation to two high level structuring principles. This includes: (1) the crew duty status (i.e. on or off duty) and (2) the crew location in the process/timeline (i.e. if on duty).

Firstly, crew task requirements vary according to their duty status. To date, this is not considered in the literature. Perhaps this reflects an assumption that tasks performed while off duty have no impact on the Active Flight Operation. If so, this reflects a narrow view of Flight Crew task activity. As demonstrated, Flight Crew engage in both briefing and reporting tasks, while off duty. Critically, these tasks have an impact on the operation. The informal flight planning and briefing activities, which the crew undertake prior to the flight/official briefing, ensure that the individual crew member is prepared for the official briefing. Moreover, this impacts on their assessment of the flight situation, which in turn impacts on the team's situation assessment activities. Reporting information is used to assess the safety/risk status of the operation, and contributes to the work of both Safety and Flight Planning personnel.

The functional logic of process dictates task performance requirements and associated workflows. This is different to the characterization of Flight Crew task workflows as evidenced in airline Flight Operations manuals. As shown, these manuals structure Flight Crew task requirements in terms of flight phases. Interestingly, this represents a process centric perspective on operational activity, as opposed to a Flight Crew centric perspective.

Flight Crew conceptualize their role and associated responsibilities in relation to several high level task functions, not accounted for in the literature. This includes team management and the management of complexity. Arguably, existing definitions of Flight Crew role fail to highlight these dimensions of task activity. Further, these definitions fail to address the important role of reporting.

This research also highlights several weaknesses in existing procedural descriptions of task activity. In opposition to airline SOPs, task workflows are not always linear. Rather, Flight Crew task workflows depend on a number of factors including (1) team task inputs at different points in the process, and (2) the specific context that pertains on the day. Flight operations manuals fail to capture the collaborative nature of Flight Crew task performance. As shown, the team dimensions of Flight Crew task performance underpin the Flight Crew role and allied task information requirements. Consistent with the research of Loukopoulos, Dismukes and Barshi (2003), research highlights the impact of context on Flight Crew task activity. Moreover, this research unpacks both what is meant by context, and how the different aspects of context impact on Flight Crew task activity. As shown, context can be conceived in terms of four high level factors. This includes operational factors, environmental factors, individual crew factors (i.e. duty status, experience of route, fatigue level, experience of aircraft type/fleet) and team factors (i.e. crew composition). Arguably, there is no 'normal' operation, but rather a spectrum of operational, environmental and team complexity - that constitutes 'normal'. In order to manage different levels of complexity, the crew are often required to optimise procedures. This necessitates much expertise. However, crew expertise cannot always be relied upon. Crew complacency in relation to the execution of SOPs is a real issue.

In agreement with Hutchins Distributed Cognition framework (2005a), Flight Crew task performance is shaped by the quality of tools and information available to the crew. Further, in accordance with Endsley (1995b; 1999a; 2000; 2001), information is central to task performance. Specifically, it forms the basis of crew situation assessment and decision making activities. Thus, delays obtaining information, and/or incomplete flight information impacts negatively on the development of a situation picture and related decision making.

This research also illuminates several non technical functions. The situation assessment process involves more than what is currently conceived. Current formulations focus on the assessment of a subset of information parameters broadly related to the 'aviate' and

'navigate' task functions. This includes: weather, routing, and terrain. Arguably, Endsley's (1988, 1995a, 1995b) definition of situation assessment might be extended to include an evaluation of the status of the operational process, the aircraft, the cockpit crew, the broader team and the quality of information available. Also, Funk's (1991) conception of task management might be broadened to include the broader team dimensions of this activity. Moreover, as shown, the design of airline operational and organisational processes impact on Flight Crew information management activities. Thus, existing information management theories (Von Thaden, 2004) might be extended to take into account the process logic underpinning this activity.

Flight Crew task relationships are complex. The performance of one task is often related to performance of other tasks. All tasks involve both technical and non technical dimensions. In addition, these different task dimensions are integrated.

Flight Crew Information Flow & Process Design

Overall, this research highlights several Flight Crew task problems linked to information/information flow. These information/information flow problems can be attributed to weaknesses in the design of (1) the existing flight operations concept (i.e. Flight Crew/ATC information flow) and (2) airline operational and organisational processes. As shown, the design of these processes dictates the nature of the information communicated to Flight Crew, the specific communication process for this, and the nature of the tools used to share this information. Accordingly, this research presents a strong case for improving these processes, in order to enhance Flight Crew task performance.

The existing Flight Operations concept and associated tools and information picture available to both Flight Crew and ATC, makes Flight Crew/ATC team work and information sharing difficult. Flight Crew and ATC do not have the same information picture. ATC has a more global information picture in relation to traffic flow. However, it does not have a detailed local picture. The situation is reversed for Flight Crew. Flight Crew have detailed local information (i.e. weather, local traffic, fuel available), but limited information about the broader air traffic situation. These problems might be rectified with the introduction of new operational concepts such as Free Flight (Johnson, Battiste and Bochow, 1999). Such changes are not within the control of an airline. Rather, they require agreement all relevant stakeholders including regulatory bodies.

This research identifies several process design problems that impinge on Flight Crew task performance. Given the design of existing flight operations process, Pilots are required to pull information from different flight operations agents, including Dispatch, the Co-ordinator and Flight Operations Control. Information is not pushed to them. This necessitates that the crew perform certain information gathering tasks not defined in airline SOPs. Further and in

support of the research of Losa (2007), this often impacts on the ability of Flight Crew to follow task workflow procedures at set flight phases as defined in airline SOPs. In such cases, the crew may defer a task, or juggle several related tasks, while waiting for information. Also, many weaknesses in terms of the provision of safety information to Flight Crew were identified. Unlike the information flow problems related to the existing operational concept outlined above, these problems can be resolved by the airline. That is, by making changes to existing process design, the airline has an opportunity to improve this situation. Arguably, the introduction of an enhanced electronic flight plan provides the platform to improve Flight Operations process design, related to the sharing of both operational and safety information. The specific mechanisms for this are discussed in more detail below. However, before doing so, the nature of the pre-flight, flight planning and briefing task is first discussed.

Pre Flight, Flight Planning & Briefing task

Procedures & Performance of Briefing Task

Existing flight operations manuals provide both a high level and normative description of the pre-flight, flight planning and briefing task. This research both supplements and extends these descriptions. Normative descriptions of this task as outlined in airline SOPs do not reflect what normally happens. Firstly, a detailed briefing is not always performed. Depending on the risk status of the flight, the crew will perform a more or less detailed briefing. Nonetheless, the presence of certain flight threats triggers a detailed briefing. For example, poor weather (i.e. fog, strong winds, ice and thunderstorms) typically prompts a more detailed briefing. The briefing workflow itself is not strictly linear. Depending on the Captain's predilection, the running order of the information review may vary. Further, the crew often re-review weather, routing and fuel information to different degrees, before signing off the fuel figure. The timing and scope of crew interactions with Dispatch/Flight Operations can also vary. Many informal processes to mitigate problems with formal SOPs were identified. In this respect, many tasks are either overlooked and/or underspecified in existing SOPs. For example, as highlighted in both user interviews and observations, the various informal processes to gather information from different operational personnel are not defined in existing SOPs. Also, existing SOPs do not allude to the other briefing contexts identified in this research (i.e. the First Officer advance briefing from home, team briefing in transit to aircraft, and team briefing for the next flight in low workload periods during the flight). In addition, research highlights the briefings frequently do not follow best practice guidelines for briefing, as outlined in CRM theory.

Team Concept

The pre-flight, flight planning and briefing is very much a collaborative task. Although the Captain is in charge, the Captain confers with the First Officer. Further, depending on the risk status of the flight, the Captain may consult with both the Dispatcher and Flight Operations Control. Thus, the team concept is broader that what is currently presented in flight operations manuals/SOPs.

Use of CRM/TEM Concepts

The CRM literature provides a theoretical account of briefing in relation to team formation (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b). This study yields more concrete information about how CRM concepts are applied in practice. The briefing is Captain led. As such, the Captain initiates the review of all flight information, and the First Officer responds in kind. Thus, the Captain has a significant role, in terms of fostering positive team relations. Specifically, the overall disposition of the Captain in relation to CRM principles generally, and the particular style adopted by the Captain both before and during the briefing, has a strong bearing on the development of a solid team concept. In analysing the flight situation, the crew address both existing and potential flight threats. These are grouped in terms of three high level categories: crew, aircraft and environment. It should be noted that this taxonomy reflects the approach of a subset of crew at Airline 5 only. Specifically, it follows from a new TEM taxonomy communicated to Flight Crew in recent CRM training sessions. This may not be representative of crew TEM activities more generally at this airline, and/or TEM approaches adopted by Flight Crew at other airlines.

To date, the literature does not provide concrete information about the particular mechanisms for assessing and ranking flight threats. This study suggests that the situation assessment process and allied evaluation and ranking of flight threats, is not a strictly rational process. In assessing the flight situation, the crew review the characteristics of the flight as relayed in the Flight Plan. As part of this, the crew engage in a level of pattern matching in relation to the features of a good or bad situation. Implicit in this is the review of flight information in relation to the three different categories of threats/problems that have or may occur, and an assessment of the severity of these problems. This reflects the crew member's own insight/judgement. In this way, crew expertise forms part of this process.

Task Problems & Their Origins

The public demand for low cost flight tickets has resulted in the introduction of low cost business models. Turnaround times have been reduced, resulting in less time for Flight Crew to perform the pre-flight, flight planning and briefing task. As shown, to ensure a complete and comprehensive briefing, the crew must manage their time carefully. The requirement

(late or otherwise) to change aircraft encroaches on the time available for the briefing. Further, crew changes or flight plan changes may require the crew to perform a full or partial re-briefing. In the low cost environment, there is limited 'give' in the process, in terms of the time available for both a once-off briefing and a possible re-briefing.

A detailed briefing does not always occur. Often the Captain, and/or both crew members are complacent in relation to the requirement for a detailed briefing. This is amplified in seemingly 'routine' situations. This spans various contexts. Examples include: flying in good weather conditions, situations where one or both crew members are familiar with the route, and situations where the crew are either familiar with each other and/or are friends. Arguably, this reflects a more general complacency related to procedures and in some cases a general failure to apply procedures. This reflects the 'procedural drift' trend as proposed by Helmreich (1999) and others (Helmreich, R.L., Klinect, J.R., & Wilhelm, J.A. 1999; Klinect, J.R., Murray, P., Merritt, A., & Helmreich, R., 2003).

Several specific problems in relation to the HCI design of existing tools, and in particular, the HCI design of the Flight Plan, were identified. Firstly, the design of the existing briefing package makes it difficult for the crew to form an initial high level overview of the flight. As part of briefing, the crew are required to consult a range of tools and information resources (e.g. flight plan, navigation charts and maps). In terms of the flight plan, this comprises several resources including routing information, fuel information, NOTAMS, and weather charts. Thus, the crew are required to integrate information across these different tools. The existing Flight Plan does not perform this integration. That is, it does not provide a summary overview of the flight.

Flight plan information is often out of date. Further, the Flight Plan does not integrate relevant information inputs from different roles, involved in the Flight Operations process and other relevant processes (i.e. Maintenance and ATC). Given that the Flight Plan is mostly provided in paper format, operational information updates must be communicated to Flight Crew either in the form of an overall flight plan update (i.e. an updated paper Flight Plan), and/or via other communication channels.

Many flight plan information gaps were identified. Certain key information is either overlooked and/or insufficient information is provided. In many cases, the crew require more detailed information, above and beyond what is provided in the current Flight Plan. This spans fuel information, crew information, airport information and aircraft technical status information. Pilots often waste valuable time gathering this information. This time would be better spent on assessing the information picture, and making use of the information, in terms of flight plan decisions. This problem can be attributed to process design. This includes decisions made by both Dispatch and Maintenance in terms of what information is relevant to Flight Crew, and as such, what information is relayed to Flight Crew in the Flight

Plan. Further, the Flight Plan does not provide flight specific instruction in relation to the identification and management of known or potential flight threats. This too can be attributed to poor process design. Specifically, in the existing SMS design, flight specific feedback is not provided to Flight Crew.

Lastly, crew practice of CRM and TEM activities at the pre-flight planning and briefing stage, are critical to both the operational and safety outcome. Yet, the Flight Plan does not provide explicit CRM/TEM support.

Requirements for Improved Briefing Tools

In general the objective of a new tool supporting Flight Crew execution of the pre-flight, flight planning and briefing task should be to foster best practice in briefing, as defined in CRM theory. To this end, it should foster team concepts and support the development of team situation awareness and team decision making. Critically, the team concept includes both Flight Crew and all other operators that the crew interact with (i.e. Dispatcher, Flight Operations Control, Co-ordinator, Maintenance, Cabin Crew and Fueller). As such, an improved tool should prompt Flight Crew about the requirement to brief, provide all relevant information to support the team briefing, facilitate information sharing between the different team members, and support specific TEM activities. Further, the tool should be designed to take into account the limited time available for the briefing.

In developing this tool, there is an opportunity to address certain more general Flight Crew information flow issues arising from weaknesses in the existing process design (i.e. difficulties sharing information with other operational personnel and issues related to the lack of flight specific risk/safety assessment information in the existing Flight Plan). Moreover, the introduction of this tool might provide the opportunity of addressing issues related to procedural drift.

This is all very well in theory but how might it be done in practice? In keeping with traditional HCI frameworks/approaches, we might argue that these problems be conceptualized as HCI design problems. Thus, to solve these problems, new tools must be introduced which deliver the right information to Flight Crew, at the right time and in the right format. However, this HCI approach reflects only one side of the problem. That is, in addition to being a HCI design problem, this is also a process design problem. The process is responsible for the timely and quality delivery of appropriate information to Flight Crew and other relevant team members. Currently, this is not happening. Thus, we must conceptualize this problem both in relation to HCI frameworks and process design theory (McDonald, 2006; McDonald, 2006, Morrison, 2007; Morrison 2009).

This research suggests a potential way forward in terms of the specific HCI execution of the proposed new briefing tool. In terms of providing the right information, this potentially

includes elaborating on existing information and providing information which does not currently feature in the Flight Plan. In terms of the former, this includes more detailed information about the fuel figure and its composition, crew information, alternates information and maintenance information. In terms of the latter, this comprises various new information resources such as:

- Operational updates and changes
- Special briefings (i.e. operational and special knowledge pertaining to routes/airports)
- Flight specific risk information.

This information might be presented in electronic format. Flight plan information might be customised depending on the briefing context (i.e. on and off duty, point in the operational process and crew location). Moreover, a summary overview of flight plan information might be provided, to support a quick briefing and/or a preliminary assessment of the flight situation.

The question of when this information should be delivered to Flight Crew (i.e. timing) is an interesting one. In principle, flight plan information should be accessible from anywhere. This information should be updated in real-time and time/date stamped. As such, information should be pushed to Flight Crew, thereby reversing the current information flow process.

Certain aspects of the TEM/reporting form and the CRM briefing checklist developed by Airline 5 might be harnessed, in terms of the re-design of the flight plan. The grouping and presentation of threats/risk information might follow the taxonomy used in the TEM/reporting form. The pre-flight briefing checklist advanced by Airline 5 is designed to focus the Captain's attention on the need to forge a team concept. This same approach might also be adopted in an improved Flight Plan.

7. CONCLUSIONS

Overall, this study provides a rich insight into the socio-technical nature of the Flight Crew task both generally and in relation to the pre-flight, flight planning and briefing task.

This study highlights the importance of information from a task performance perspective. Critically, it points to certain system information flow problems arising from weaknesses in the existing process design, which impact negatively on Flight Crew task performance. Further, these process design problems impinge on Flight Crew performance of the pre-flight, flight planning and briefing task. Given the importance of the pre-flight, flight planning and briefing task, in terms of the safety and operational outcome of the flight, these process design/information flow problems require redress.

This study also identifies several other task problems pertaining to Flight Crew execution of the pre-flight, flight planning and briefing task. Crew are often complacent about the requirement to brief. Best practice in briefing as defined in CRM theory is not always put into practice. Further, there is limited time accorded to this task in the existing process design. Thus, this study underscores the requirement to introduce improved tools to assist Flight Crew performance of this task and mitigate these task performance issues.

Overall, new tools should be embedded in the Flight Operations process - providing fast access to all necessary task information. Moreover, new tools might assist crew CRM/TEM activities. In addition to enhancing Flight Crew practice of the pre-flight, flight planning and briefing task, this tool might have the added benefit of high involvement and reducing procedural drift.

This study has resulted in the definition of certain provisional requirements for an improved Flight Plan. The specific HCI design requirements for this tool require further analysis. This is the subject of Study 5. Further, the process re-design rules inherent in this new tool concept require specification. This is examined in Study 6.

Study 5: Participatory Design and Evaluation of High Level Flight Tool Concept, to Support the Pre-flight, Flight Planning and Briefing Task

1. CHAPTER INTRODUCTION

This chapter reports on the findings of the fifth HILAS study, the participatory design and evaluation of a new tool concept supporting Flight Crew performance of the pre flight, flight planning and briefing task. This research was undertaken following all prior studies, and involved the participation of Pilots from Airline 5 only.

The prior studies suggested several requirements for an improved tool, assisting Flight Crew performance of the pre-flight, flight planning and briefing task. Further, these studies highlight the necessity of advancing new flight operations processes and tools to facilitate the intelligent use of airline operational and safety data. Critically, research indicates that these new processes and tools are central to the advancement of improved Flight Crew tools. Collectively, it is necessary to translate these requirements into new tool concepts. Three phases of research were undertaken. In the first phase, the researcher analysed and specified the emerging requirements for a new tool assisting Flight Crew performance of the pre-flight, flight planning and briefing task. High level prototypes were then developed. Following this, these prototypes were further specified and evaluated, with a panel of Pilots involving two phases of participatory research.

2. RESEARCH DESIGN

Objectives

The objective of this study was to advance the HCI requirements for an improved tool facilitating Flight Crew performance of the pre-flight, flight planning and briefing task.

Overall Analysis of Flight Crew Tool Requirements & Generation of Tool Concepts

Prior to embarking on the prototyping and evaluation activities, a number of analysis steps were first undertaken. Specifically, the collective findings of the four studies were analysed in relation to the identification of tool requirements supporting the pre-flight, flight planning and briefing task. This involved an analysis of the implications of the emerging task models (i.e. overall Flight Crew task model, and specific model of the pre-flight, flight planning and briefing task) in relation to new tool requirements. Flight Crew feedback in relation to existing tools problems and the requirements for improved tools were also considered. Further, tool requirements were also analysed in relation to the broader flight operations context. In this regard, process design and information flow issues in relation to the Flight Planning process (i.e. Study 2), and the Safety/Quality/Improvement Process (i.e. Study 3) were also considered. Collectively, these findings were translated into a series of high level requirements for an improved pre-flight, briefing tool and associated tool functions. As highlighted earlier, the emerging task model distinguishes Flight Crew pre-flight, briefing requirements in different contexts (i.e. when on and off duty, in different crew locations, at different points in the operational process, and at a team and individual level). Accordingly, Flight Crew task information requirements were analysed in terms of these different contexts, as outline in Table 24 below.

Table 24: High Level Functions, On and Off Duty (Study 5)

#	Duty Status	Crew Location	Operational Timeline/ Process	Example High Level Functions		Self	Team
1	Off duty, free day	At Home	N/A	1	Login	Y	N
				2	View read only flight plan information pertaining to future flights	Y	N
2	Off duty, free day	In Office	N/A	As above		As above	
3	Off duty, crew pairing	In hotel	N/A	As above		As above	

4	On duty, training day	In Office	N/A	As above		As above	
5	On duty	In Crew room	Pre flight (flight planning and dispatch)	1	Login	Y	Y
				2	View Summary Information (relevant to flight)	Y	Y
				3	View flight plan information, including aircraft technical status information.	Y	Y
				4	Make flight plan changes (e.g. fuel, alternates, flight level) and signoff plan	N	Y
				5	View information about flight threats/risks	Y	Y
				6	View briefing guidance	Y	Y
				7	Send and receive messages	N	Y
				8	View related documentation	Y	Y
6	On duty	At Aircraft	Any point in flight (e.g. pre flight, flight execution, post flight)	1	Login	Y	Y
				2	View Summary Information (relevant to flight)	Y	Y
				3	View flight plan information, including aircraft technical status information.	Y	Y
				4	Make flight plan changes (e.g. fuel, alternates, flight level) and signoff plan	N	Y
				5	View information about flight threats/risks	Y	Y
				6	View briefing guidance	Y	Y
				7	Send and receive messages	N	Y
				8	View related documentation	Y	Y

				9	View flight plan information for next flight	Y	Y

Following from this, the requirements for three tool concepts supporting the Flight Crew briefing in these different contexts were advanced. This includes: (1) Personal, (2) Dispatch and (3) Electronic Flight Bag (EFB). Table 25 presents a high level overview of these applications. This includes a high level summary of each tool in relation to when it is used (i.e. duty status and point in the operational process timeline), where it will be used (i.e. the crew location), whether it is used by an individual crew member or both crew members, the particular device used and the level of functionality provided.

Table 25: Overview of Flight Crew Applications (Study 5)

Application	Personal (logged in)	Dispatch	EFB
Duty Status	Off	On	On
Operational Timeline	N/A	Pre flight: flight planning and briefing	Pre-flight/turnaround, Flight execution, Post flight
Location	Anywhere: home, office, crew hotel	Crew room	Aircraft/cockpit
Use	Individual	Team	Individual & Team
Device	Personal Computer or laptop	Personal Computer	EFB Class 1 (tablet and stylus)
Functionality	Pre flight – flight planning and briefing – future flights	Pre flight – flight planning and briefing – current flight, next flights	Pre flight – flight planning and briefing – current flight, next flights
	N/A	Messaging/communications	Messaging/communications
	N/A	Documents	Documents

Further, the Researcher specified at a high level, the high level requirements for broader flight operations processes and tools, underpinning these new Flight Crew tool concepts. A high level summary of these is provided in Table 26 below.

Table 26: Flight Operations Process Redesign and New Tool Requirements (Study 5)

#	Process	Process Redesign Requirement	Associated New Tool Requirement
1	Flight Planning	Improve information flow within the airline to support (1) flight planning and (2) dispatch	Integration of the airline's SMS and Flight Planning tools
			Integration of the airline's SMS and Dispatch tools
2	Active Flight Operation	Improve information flow within the airline to support (1) flight operations management (e.g. role of Duty Manager) and (2) Flight Crew information Sharing with other roles during the active operation	Integration of the airline's SMS and Flight Crew tools
			Integration of the airline's SMS Flight Operations Control tools
3	Improvement/Safety/Quality	Improve performance management/safety management processes to support real-time risk management	Support the intelligent use of safety/performance/risk information within the airline
		Improve associated feedback processes, specifically in relation to (1) Flight Planning/Dispatch, (2) Flight Operations Control and (3) Flight Crew	Improve existing performance management/safety management tools – specifically in relation to data gathering, data integration, data analysis and feedback mechanisms

Initial Prototyping

The Researcher then produced high level HCI prototypes for the three tool concepts, using an off the shelf prototyping tool - Microsoft Visio. A basic prototype was developed for (1) the Personal application, (2) the Dispatch application and (3) the EFB application. Not all of the screens for each of the applications were developed. The login and default screen for each application was created. In addition, the outline for a sub set of each of the main menu items was developed. The outline described high level task workflows and associated user interface information. It was anticipated that these screens would be used to problem solve user requirements and specify actual user interface information and workflows, as part of the participatory modelling and evaluation sessions with Flight Crew. Further, it was intended to update interface screens with additional information, through the course of these sessions. Table 27 provides a summary of the initial user interface screens developed.

Table 27: User Interface Screens Developed for the First Stage of Participatory Design (Study 5)

#	High Level Function	Screens Developed			
		Personal (Not Logged In)	Personal (Logged In)	Dispatch	EFB
1	Login	N/A	Login	Login	Login
2	Overall Summary / Home	Home	Home	Home	Home
3	Flight Plan (Current Flight & Next Flight)	N/A	N/A	Flight Plan Summary	Flight Plan Summary
				Flight Plan – TEM/Briefing	Flight Plan – TEM/Briefing
				Flight Plan / Routing & Alternates	Flight Plan / Routing & Alternates
				Flight Plan / Fuel	Flight Plan / Fuel
4	Advance Flight Plan	N/A	Future Flight Plan Summary	Future Flight Plan Summary	Future Flight Plan Summary
5	Communications	N/A	N/A	Communications Summary	Communications Summary
6	Documents	N/A	N/A	Documents Summary	Documents Summary

Examples of the preliminary prototypes developed for the Dispatch application are provided below. Figure 3 illustrates the login screen for the Dispatch prototype. Figure 4 demonstrates the default screen for the Dispatch prototype. Figure 5 depicts the Flight Plan summary screen for the Dispatch prototype. Further examples are available in Appendix 8.

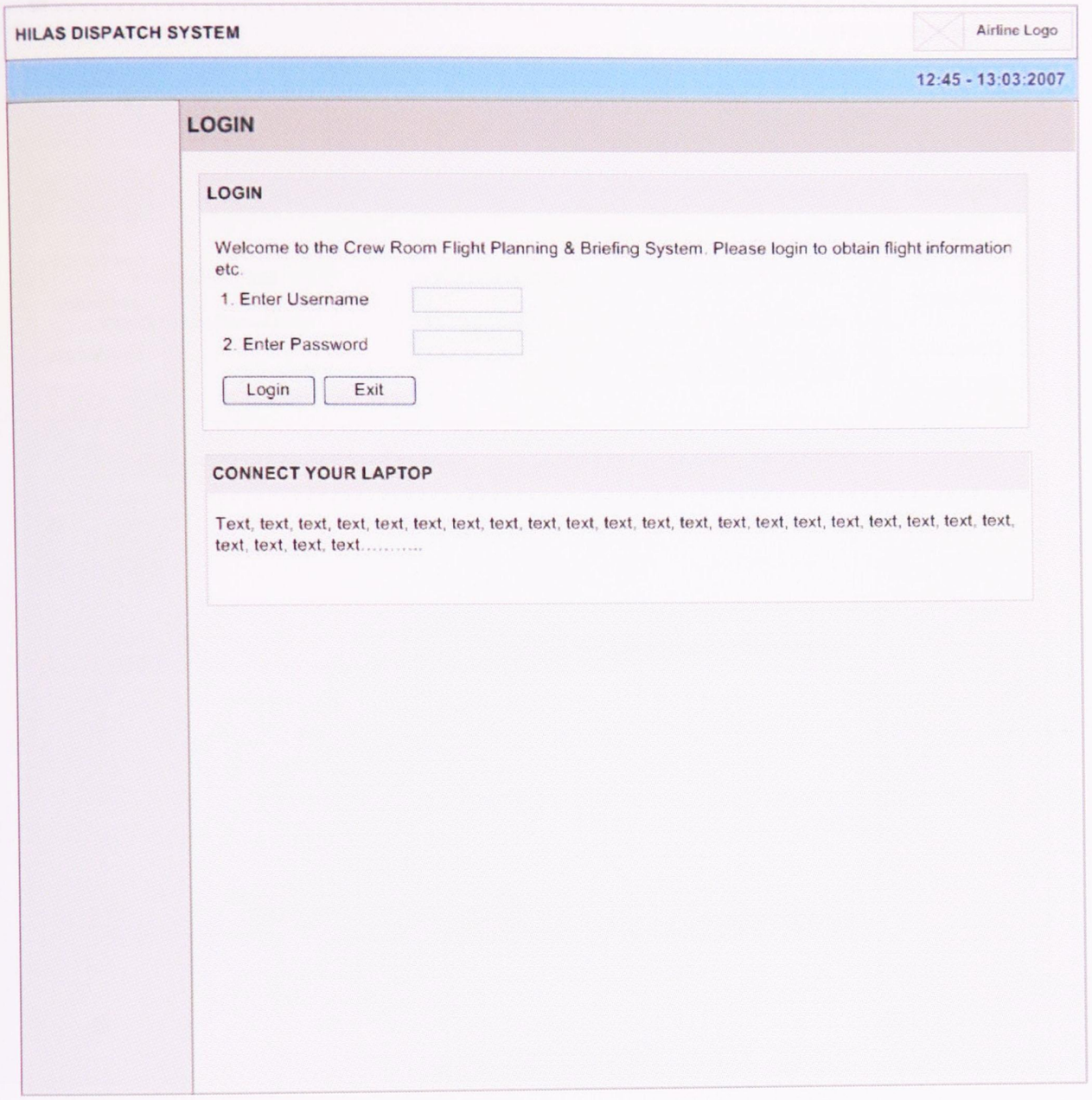

Figure 3: Dispatch Application, Login Screen (Study 5)

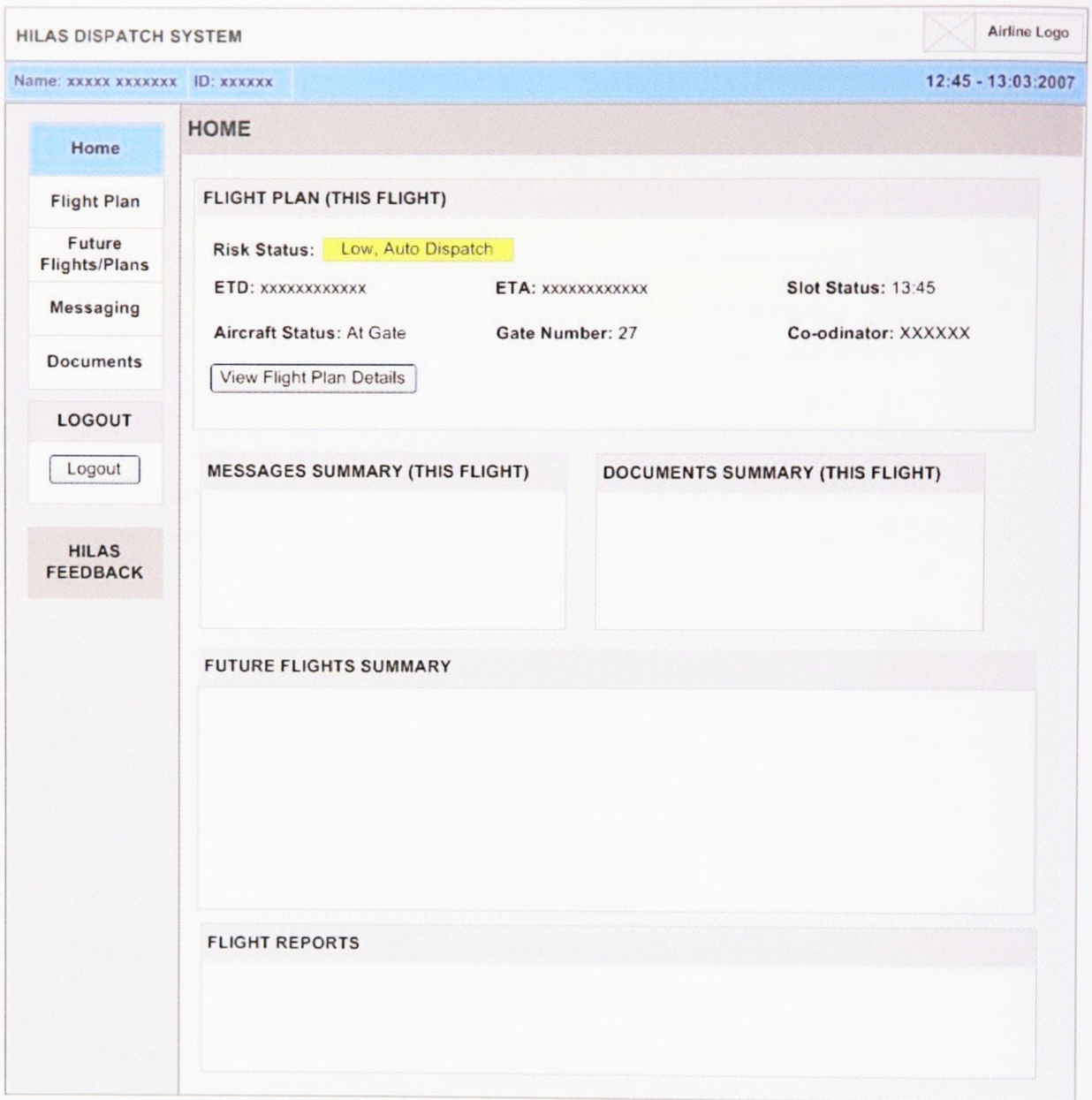

Figure 4: Dispatch Application, Default Screen (Study 5)

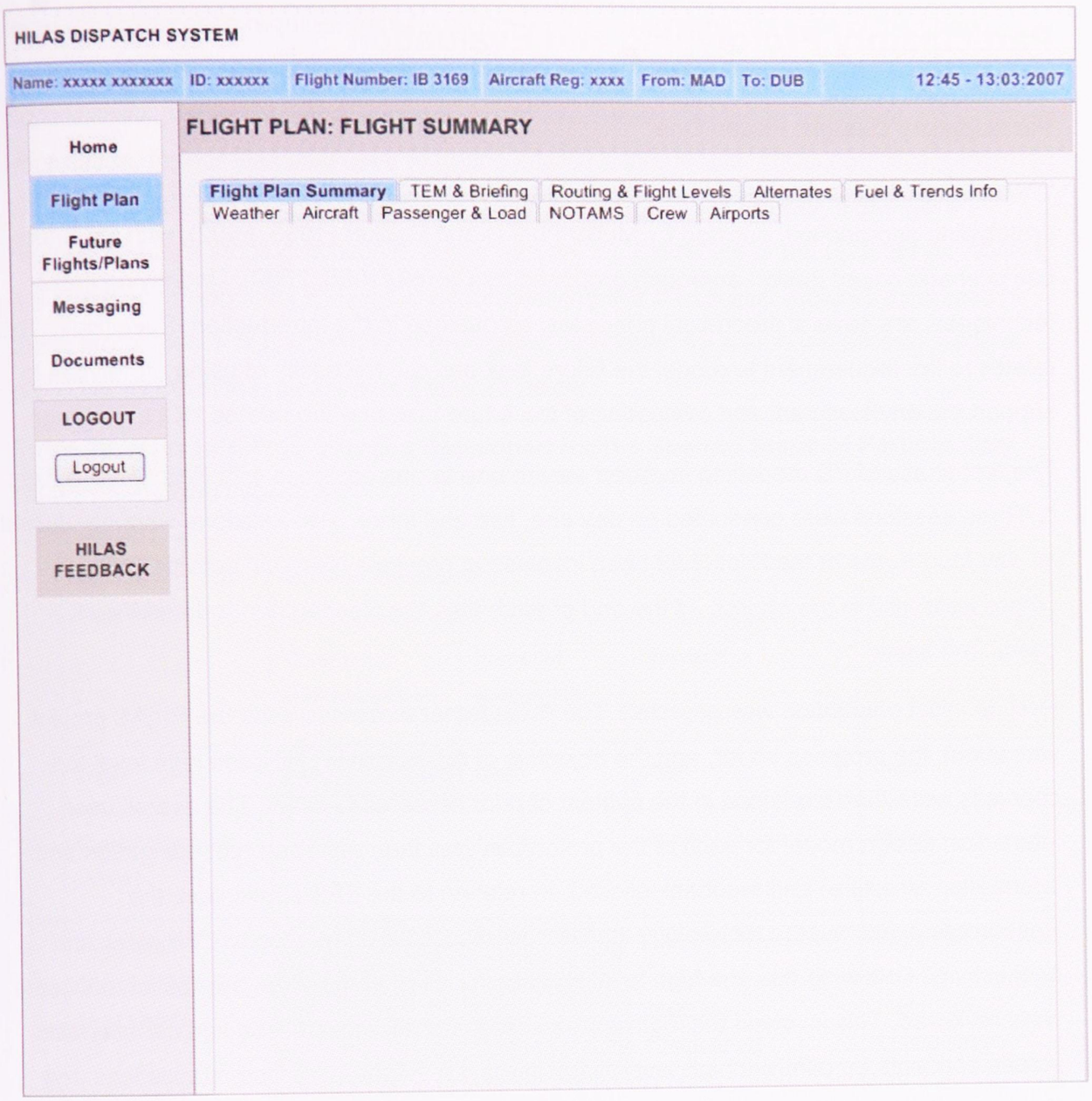

Figure 5: Dispatch Application, Flight Plan Summary (Study 5)

Participatory Prototyping and Evaluation

Participatory Design: Phase One

The research design involved the integration of technology envisionment and collaborative prototyping approaches, outlined by Muller (1991) and Bodker (1985, 2002), with the future use scenario based design approach proposed by Carroll (1995, 2000). Underlying these techniques, are several theoretical principles, as outlined in the introduction. Specifically, this relates to the requirement to model the future task and the necessity of using prototypes to support the envisionment and evaluation of the future task and the related HCI tool design.

The first phase of PD modelling involved eleven one to one sessions with Pilots from Airline 5. Three sessions were conducted on day one, two and three. Two sessions were conducted on day four. Some of the Pilots had been involved in previous research activities, while others were new to the project. At the end of each day, the Researcher updated the HCI design model.

First an initial orientation was provided. The Researcher explained what the HILAS project was about, the progress so far, and the objective of the session. The three high level tool concepts were then explained in the context of prior research findings. The overall user interaction design model for each of the prototypes was then reviewed (i.e. navigation and information structure) and feedback elicited. In relation to the EFB application, the Researcher explained the technology limitations, specifically in relation to EFB class and connectivity. Following this, the high level screens for each of the three application concepts were reviewed. This involved the login screens for the three applications and certain basic screen concepts for different high level menu items (i.e. Flight Plan, Communications and Documents). Prototype screens were used as a basis from which to establish more detailed requirements concerning task workflows, information requirements and information structure and presentation. As part of this, the Researcher posed questions in relation to both information in and information out. In relation to information in, participants were questioned as to what information they expected to see on each screen, where the information might be located and how they might access information. In relation to information out (i.e. communications tasks), participants were asked questions in relation to what information they would like to send, to whom, and for what purpose. Some of the Flight Plan screens were not fully developed (i.e. TEM/briefing, routing and alternates, and fuel screens). In these cases, the Researcher presented a blank screen and asked participants what they expected to see. Participants were also invited to draw out concepts and/or suggest edits to the existing prototypes.

Following the first phase of participatory activities, the prototypes were further modelled, taking into account participant feedback. This involved detailing the specific workflows and

interface information requirements for all the high level screens, for each of the three applications. Also, new screens were modelled in line with the emerging requirements. To support crew problem solving, doctored information was provided to represent actual screen information. Colour was also used to define interface information areas and information priority. The specific graphical design of icons was not detailed. Rather, icons were represented by a stock graphic (i.e. a box with an 'x'). Examples of the updated prototypes are provided in Appendix 9. The CD accompanying this thesis also features examples of these prototypes. For a summary of the screen developed for use in the second stage of participatory sessions, please see Table 28 below.

Table 28: User Interface Screens Developed for the Second Stage of Participatory Design Sessions (Study 5)

#	High Level Function	Screens Developed			
		Personal (Not Logged In)	Personal (Logged In)	Dispatch	EFB
1	Login	N/A	Login	Login	Login
2	Overall Summary / Home	Home	Home	Home	Home
3	Flight Plan (Current Flight & Next Flight)	N/A	N/A	Flight Plan Summary	Flight Plan Summary
				Flight Plan – TEM/Briefing	Flight Plan – TEM/Briefing
				Flight Plan / Routing & Alternates	Flight Plan / Routing & Alternates
				Flight Plan / Fuel	Flight Plan / Fuel
				Flight Plan /NOTAMS	Flight Plan / NOTAMS
				Flight Plan /Crew	Flight Plan /Crew
4	Advance Flight Plan	N/A	Future Flight Plan	Future Flight Plan	Future Flight Plan
5	Communications	N/A	N/A	Communications Summary	Communications
				Compose and Send Message	Compose and Send Message

				View Message Details	View Message Details
					Send Message Prompt
					Communications/Synchronization Prompt
6	Documents	N/A	N/A	Documents Summary	Documents Summary

Participatory Design: Phase Two

Phase two sessions were conducted over two days. On the first day, a full day group evaluation session with four Pilots was conducted. The panel included a mix of Captains and First Officers, some of whom were involved in CRM training. These Pilots were participants in the Process Mapping session (i.e. Study 1), the study of airline CRM/TEM activities (i.e. Study 3:3), and the Flight Crew task analysis (i.e. Study 4). First, the researcher presented the updated prototypes for each of the three application concepts. Participants were invited to review the screens for each of the three applications, to ensure that the updated screen information and interaction design was appropriate. As part of this, participants were invited to suggest HCI improvements, where appropriate. HCI problems and design solutions were discussed and agreed collectively. Quick design fixes were made by the Researcher during the course of the session. More complex changes (i.e. in relation to interaction flow) were reviewed on a blackboard and updated by the Researcher at a later point that day. This session also focussed on specifying additional user interface screens. This specifically relates to the Intelligent Flight Plan (current flight) and the messaging/communications modules.

On the second day, the Researcher reviewed the emerging HCI design model, with one Pilot. This Pilot was involved in the collaborative prototyping and evaluation activities, undertaken the previous day.

Following this, the Researcher presented the design concepts to a group of airline flight operations and IT staff. First, the Pilot involved in all previous sessions, provided an introduction to the project and the airline's role. Following this, the Researcher presented the tool concept for the different briefing contexts. As part of this, particular user interface screens were demonstrated. Feedback regarding the HCI design solution was elicited.

The collective feedback from all three sessions was then analysed. The proposed user interface screens were updated and additional screens modelled. Examples of these screens are provided in Appendix 10. The CD accompanying this thesis also features examples of these prototypes. For a summary of these screens, please see Table 29 below.

Table 29: User Interface Screens Developed after the Second Stage of Participatory Design Sessions (Study 5)

#	High Level Function	Screens Developed			
		Personal (Not Logged In)	Personal (Logged In)	Dispatch	EFB
1	Login	N/A	Login	Login	Login
2	Overall Summary / Home	Home	Home	Home	Home
3	Flight Plan (Current Flight & Next Flight)	N/A	N/A	Flight Plan Summary	Flight Plan Summary
				Flight Plan – TEM/Briefing	Flight Plan – TEM/Briefing
				Flight Plan / Routing & Alternates	Flight Plan / Routing & Alternates
				Flight Plan / Fuel	Flight Plan / Fuel
				Flight Plan /NOTAMS	Flight Plan / NOTAMS
				Flight Plan /Crew	Flight Plan /Crew
				High Involvement	High Involvement
				Flight Plan Signoff	Flight Plan Signoff
4	Advance Flight Plan	N/A	Future Flight Plan	Future Flight Plan	Future Flight Plan
5	Communications	N/A	N/A	Communications Summary	Communications
				Compose and Send Message	Compose and Send Message
				View Message Details	View Message Details
					Send Message Prompt
					Communications/Syn

					chronization Prompt
6	Documents	N/A	N/A	Documents Summary	Documents Summary

Participants

Overall, this study involved the direct participation of 15 participants. A breakdown of participants is provided in Table 30 below.

Table 30: Breakdown of Participants (Study 5)

Phase	Participant Number	Role	Day
1	1	Captain	1
	2	First Officer	1
	3	Captain	1
	4	First Officer	2
	5	Captain	2
	6	Captain	2
	7	First Officer	3
	8	First Officer	3
	9	Captain	3
	10	First Officer	4
	11	Captain	4
2	12	Captain / CRM Trainer	1
	13	First Officer / CRM Trainer	1
	14	First Officer / CRM Trainer	1
	15	First Officer / CRM Trainer	1
	13	First Officer / CRM Trainer	2

		(Same as previous)	

The group session was attended by a range of Flight Operations personnel, including seven Pilots, four Cabin Crew representatives, three Flight Operations Control personnel, one Dispatcher, one representative of the airline's Dispatch Department, three representatives of the airline's Safety department and the Head of Flight Operations. Also two representatives of the airline's IT department attended the group session.

3. RESULTS

Participatory Design & Evaluation, Phase 1

Overall Tool Concepts

Participants responded favourably to the three integrated tool concepts (i.e. remote web application, crew room application and EFB application). In keeping with prior research, participants reported that task requirements and associated information needs vary according to their duty/roster status. Further, participants reported that if on duty – their task and information requirements vary according to their location in the process (i.e. pre-flight, flight execution and post flight) and their physical location (i.e. crew room and aircraft). Participants indicated that each of the applications reflected what they expected or would like to do in these different contexts.

Three participants noted that the overall tool framework might be extended to include portable digital assistants (PDA's). These participants remarked that PDA's are always on their person and facilitate communication from anywhere. Moreover, these participants stated that they would like to synchronise their PDA with the Personal and Dispatch applications. Participants did not expect to synchronise their PDA with the EFB application. Further, two participants indicated that they would like to access the Dispatch application from their laptop.

Three participants stated that some kind of remote access to flight information is necessary for crew members who do not live close to the airline. These participants stated that they often travel to work to obtain this information, even when they are off duty.

All participants were aware of existing EFB devices, and felt that the airline should be deploying EFBs. Overall EFBs were perceived as enhancing both safety (i.e. better access to information and facilitating communication) and efficiency (i.e. cost saving resulting from information communication improvements).

Three participants indicated that these tool concepts necessitate the development of corresponding tools for use by other airline personnel to send/receive data. Participants

referred to a range of functions including Flight Planning, Flight Operations Control, Safety/Risk Manager and Dispatch. Further, it was noted that this would require improved processes for sending/receiving information. Three participants reported that the introduction of this tool would necessitate changes to a number of airline processes. One participant stated *"This is not always easy - the airline is not good at changing"*. The same participants observed that "*the technology will only work, if people are willing to change their work practices*".

Intelligent Flight Plan Concept

Overall

Participants welcomed the provision of task support in relation to the pre-flight, flight planning and briefing task. Participants responded positively to the three versions of the Flight Plan: (1) current flight, (2) next flight or flights later that day and (3) future flights. As stressed by a First Officer, *"this facilitates flight planning and briefing in all contexts"*.

Participants responded positively to the idea that the Flight Plan exploits the output of airline SMS analyses. In particular, the provision of risk information related to their specific flight was welcomed. In this respect, participants understood the link between crew reporting, the analysis of safety data, the generation of flight specific CRM/TEM information and the associated Intelligent Flight Plan concept.

It was agreed that the following risk information should be provided: (1) an overall assessment of the risk status of the flight, (2) an assessment of flight risks in relation to three categories of threats (e.g. crew, aircraft and environment), (3) detailed information about particular flight threats identified, in each of these categories and (4) best practice information in relation to the management of potential threats or errors.

Participants proposed that the risk assignment for a given flight and the associated dispatch requirement (i.e. auto-dispatch and/or person to person dispatch), would be based on an analysis of (1) the number and severity of flight threats in three different threat categories - namely crew, aircraft and environment, and (2) the probability of their occurring. Participants agreed that the risk status of the proposed flight be ranked in relation to three risk levels: low, medium and high. In principle, these risk levels correspond to the different ways in which the crews characterize a flight situation (i.e. good, bad, and 'in between'). Participants raised a number of questions concerning the implementation of this risk logic. Moreover, participants questioned the reliability of such a risk estimate. In this respect, four participants suggested that the overall risk rating might be difficult to calculate. One First Officer remarked: *"it is not simply a question of adding each of the risk values; the combination of risk values needs to be factored"*. The specific process for this was not explored at this point.

Participants provided examples of threats in each of the three risk categories. In relation to aircraft threats, participants noted the ranking of threats should follow the minimum equipment list (MEL) rankings and requirements, as defined in relevant aircraft maintenance manuals. It was noted that certain aircraft technical issues are 'no go' items, and as such, if they occur, the aircraft cannot depart. Nonetheless, participants stated that certain technical issues are permissible with the MEL, but can impact on task workflows (i.e. APU unserviceable). In this respect, participants observed that providing information about aircraft threats would be useful. Participants referred to a range of environmental threats. All participants noted that the nature of the weather on the day contributes to flight complexity and crew workload. In addition, participants reported that certain routes are more complex to fly given (1) the volume of traffic and ATC traffic management styles, (2) the complex geography (e.g. high terrain), (3) weather conditions at certain times of year, (4) the complexity of approach at the destination airport, (5) the CAT status of airport and (6) the availability of airport navigational equipment (i.e. ILS). It was stated that these factors might be taken into consideration in the assessment of environmental threats. Participants alluded to a range of crew composition threats that might impact on the flight. This includes fatigued crew, inexperience First Officer flying with New Captain, inexperienced First Officer flying with Captain with minimal experience of specific aircraft type, and crew with limited experience of specific routing/airports.

It was suggested that the generation of risk/threats information related to aircraft and environmental factors might be straightforward. As noted by several participants, maintenance systems and the technical log feature up to date information about the aircraft technical status. Ideally, Flight Planning personnel might have access to this information, such that potential issues are taken into account at the flight planning and dispatch stages, and/or flagged to crew in terms of the Flight Plan. Further, participants observed that certain environmental threats (i.e. bad weather and ATM issues) might be known before the flight, and relayed to Flight Crew. Nonetheless, it was observed that these threats very often manifest in real-time. However, participants suggested that the risk assessment of crew factors might be more complex.

Current Flight

Overview

All participants welcomed the idea of obtaining an electronic version of the Flight Plan. Further, all participants welcomed the automation of certain functions (i.e. fuel request, alternate request and flight level request). Participants noted that the current process requires Flight Crew to consult with Dispatch to action these changes. It was agreed that this is unnecessary for routine flights. However, two participants observed that it is essential that Dispatch and/or Flight Operations Control are involved in flight planning activities, for flights

with a high risk profile (i.e. adverse weather conditions, crew composition issues and/or aircraft technical issues). In the words of one participant, *"it is good to have other eyes look over the plan"*. Two pilots suggested that the workflow (and SOP) should prohibit Flight Crew from dispatching a flight with a high risk profile. In such cases, Flight Crew should be required to co-dispatch the flight with a representative from Dispatch and/or Flight Operations Control. Accordingly, two dispatch processes were proposed. Flights with a low risk rating would take the form of an auto-dispatch. Conversely, a person to person dispatch with the Dispatcher would be required for flights with a risk rating of medium or above. The specific nature of this process was not defined in detail at this point.

Flight Plan Summary (Operational Updates & Risk Rating)

All participants remarked that the provision of flight plan summary screen is useful, insofar as it provides an overview of the flight status and all critical information. In particular, participants welcomed the provision of information concerning operational updates and/or changes. All participants noted the Flight Plan can be out of date, or there may be last minute changes and the information is not always available to them. Participants suggested that key information includes aircraft location, aircraft technical status, runway status, crew status, passenger status (including information about free tickets/airline ID tickets), weather status and overall flight/risk status. Participants stated that once changes are made, this information should be communicated/sent to them in real-time, or as close to real-time as is possible. All participants welcomed the assignment of an overall risk rating for a flight, and the associated summary information. All participants reported that the existing threat taxonomy used by the airline - namely aircraft, crew and environment – is intuitive. All participants understood the colour coding beside each of the risk categories. All participants noted that they would expect to find more detailed information concerning specific flight threats or issues in the TEM/briefing section.

The updated version of the Flight Plan Summary Screen for the Dispatch application (i.e. following the first phase of collaborative prototyping and evaluation activities) is depicted in Figure 6.

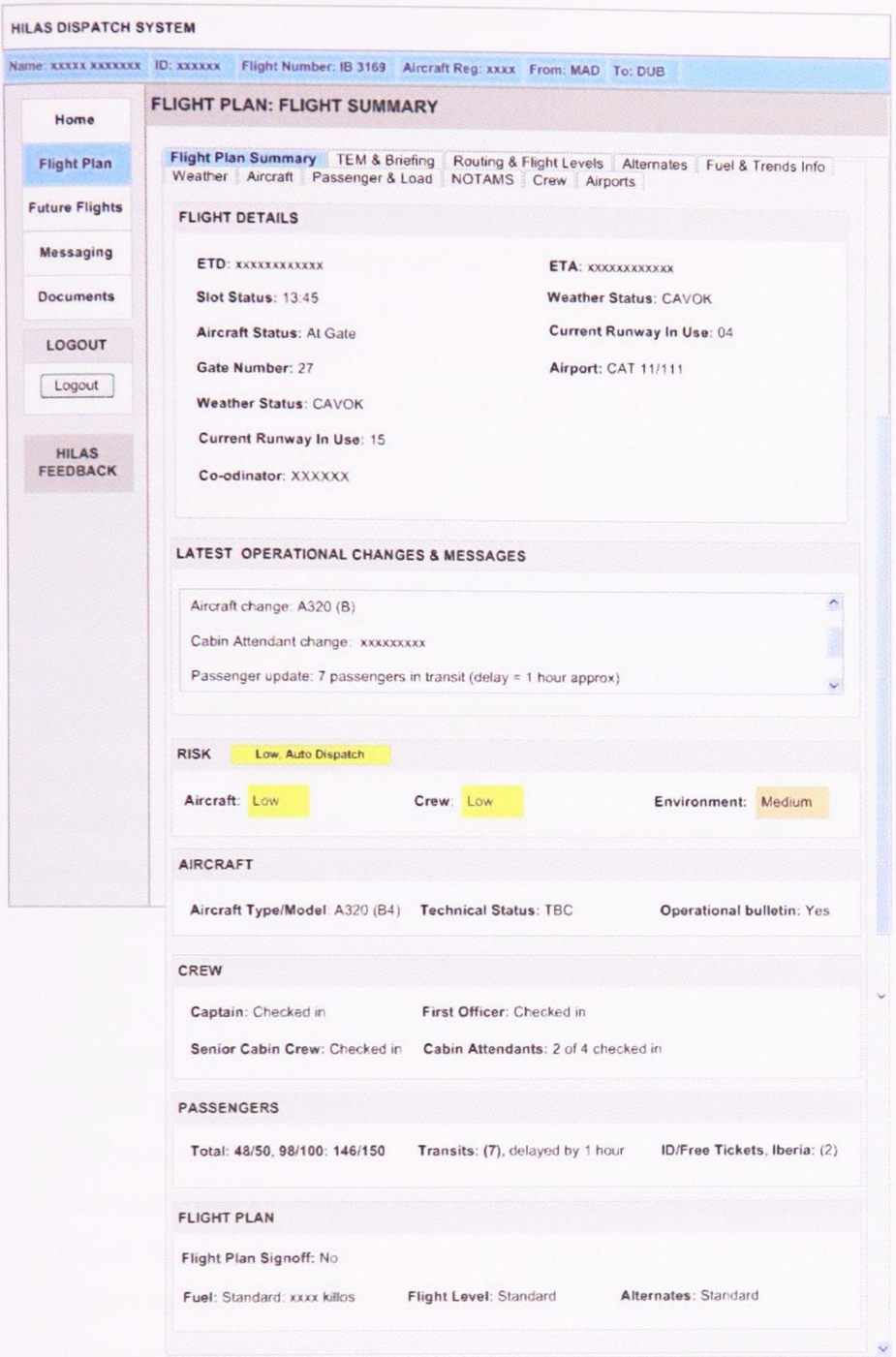

Figure 6: Dispatch Application, Flight Plan Summary (Study 5)

Risk, TEM & Briefing

In general, participants welcomed the idea of obtaining customised threat information for their specific flight (i.e. more detail than on summary screen).

Participants liked the idea of providing TEM review input at the flight planning/briefing stage. In this respect, a number of participants suggested that they would not expect the system to be aware of all threats. Further, these participants noted that the crew might obtain information about new threats to be considered in real-time, following real-time feedback from other crews, or Dispatch, or Flight Operations Control. Participants stated that the crew might also record this information.

Consistent with the earlier interviews, participants compared the state of being briefed or *"being aware of flight threats"* with being *"situationally aware"*. All participants felt that the customised flight briefing would be useful at the flight planning/briefing stage. Overall, feedback suggested that this would facilitate teamwork and the development of a *"common situation perspective"*. Participants noted that they do not always have the time to do this. One First Officer observed that *"the briefing screen externalizes what crews already know but sometimes forget"*. Two participants remarked that it might be useful to send elements of this same briefing to Cabin Crew. For example, Flight Crew might select the specific parts of the briefing relevant to the Cabin Crew and then send these to the crew.

Flight Plan for Next Flight or Other Flights that Day

All participants welcomed the possibility of obtaining flight plan information for their next flight on the EFB. Participants noted that they usually have time to review information related to the next flight, in the case of flights with longer cruise times. Consistent with earlier research, participants reported that this is good workload management practice. Overall, there was a lack of consensus in relation to the level of functionality which might be provided. Some participants suggested that the EFB should provide read only access to summary flight plan information and prompt users to use ACARS to action any flight plan changes/requests. Other participants felt that the EFB should provide access to flight plan change functions (i.e. request additional fuel, change flight level and change alternate), albeit these functions would only be active once on the ground. Two participants stated that it would be confusing to present these functions while in flight, if these functions are only activated while on the ground.

Future Flights

All participants welcomed the possibility of receiving advance flight plan information. Participants noted that the future flights list should contain filters for special flights, domestic flights and international flights. Participants stated that a timeline filter (i.e. today, tomorrow, this week and next week) is also useful. All participants noted that this function should

primarily focus on providing static operational information. This includes: charts, airport information, hotel pick up times, and crew information. That said, participants suggested that this might also include certain lifestyle information. For example, this might include hotel information, information about the location and information about special holiday/religious days. All participants noted the provision of advance information about fellow crew members (i.e. flight experience and crew photographs) supports team building.

Figure 7 depicts the updated version of the Future Flights screen, for the Personal Application.

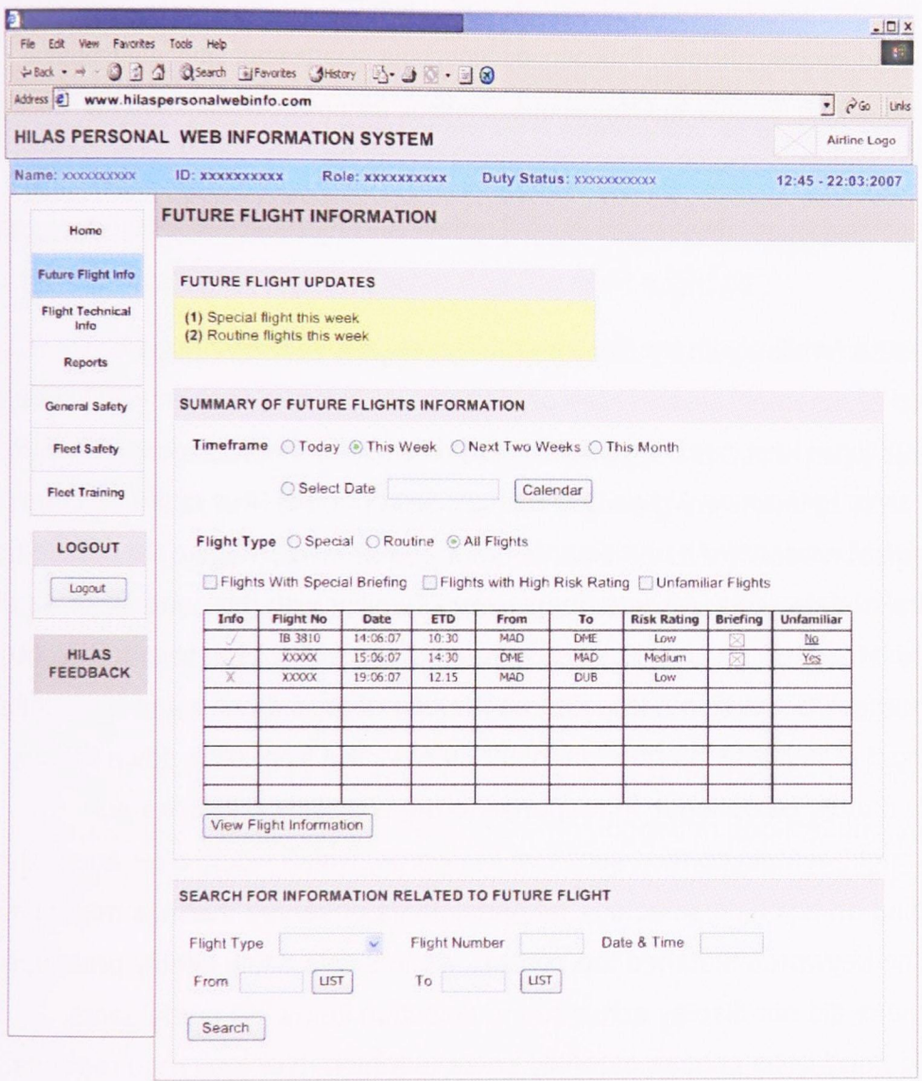

Figure 7: Personal Application, Future Flights (Study 5)

EFB

Participants suggested that the transition from paper to electronic tools would be beneficial from a workflow and information access perspective.

Participant feedback suggests a strong expectation that the EFB will connect to aircraft systems (minimum of Class two), so that real time information sharing with other operational roles is obtainable.

All participants observed that the requirement to synchronise information (i.e. send and receive updates) creates additional workload for crew, and that a real-time data link is preferable. Overall, feedback suggested that this workaround would be acceptable in the short-term, but not sustainable over the mid to long term. All participants welcomed the presentation of summary communications information on each screen. One participant noted that *"the display of last communication time was useful"*.

All participants indicated that they would require some kind of prompt to remind them to communicate. Further, it would be essential to provide some visual indication of the currency of this information. As before, participant emphasized that the older technologies are still useful (i.e. VHF Radio and mobile phone). Further, participants suggested that in certain cases, it might be easier to talk directly to Operations Control, as opposed to sending them a message using the EFB and/or Dispatch communications functions.

All participants remarked that in an ideal world, both Captain and First Officer would have an EFB.

Only four participants were familiar with the Stylus and Tablet (this was described to participants as opposed to demonstrated). Three participants suggested that the EFB should use a tablet that has a pull out keyboard. One participant referred to the inter-console which is being used for data entry in the new Airbus 380 design. As reported: *"this could be used for data entry for all cockpit devices"*. All participants noted that relevant flight data should be pre-populated, to minimise data entry. All participants were familiar with the concept of a soft alphanumeric keyboard. However, all participants expressed concern that data entry might be quite slow. In this respect, all participants welcome the use of drop down menus. Further, it was observed that most mandatory information might be selected from drop down menus and that free text fields should be optional. In response to the suggestion that the soft alphanumeric keypad might contain context sensitive keywords, which would alter according to context (i.e. depending on text field selected), all participants observed that this might be a good idea, assuming the keywords matched the context. As this was a low fidelity prototype, specific data input screens did not display actual menu selection items. All participants stated that these would need to be chosen carefully so as to match user task requirements and likely data entries.

General HCI Feedback (All Applications)

Login Requirements

All participants expected some kind of security clearance in relation to the application login. The nature of this varied according to the specific application used. For the remote web application, participants expected to login using their username and ID/password. Participants stated that this would be required, given that they would be logging into the system on their own (i.e. individual situation). All participants noted the crew room

application would be a group activity. For the crew briefing room application, participants expected that either the Captain or the First Officer would login with the Flight Number and their username and ID/password. As such, the application login should not be restricted to the Captain. It was noted that certain aspects of this application (i.e. fuel signoff) would require Captain Signoff, in which case the Captain would append his/her signature. In relation to the EFB login, all participants expected that the login would work similarly to the briefing room application. Participants pointed out that if there were two EFBs, each crew member would login using flight number, name and ID/password.

Application Summary Screen

All participants welcomed a summary screen on logging in. In the case of (1) the crew briefing room application and (2) the EFB application, all participants indicated that the flight summary screen was the appropriate default screen. As stated by one participant: *"the provision of summary flight information including information about operational risks allowed them to interpret at a glance what way the flight might go*".

In relation to the remote web access application, participants noted that they expected it to be another version of the home page with their details. Participants understood the 'my information updates' section, on viewing the logged in home page. All participants felt that this was useful, and would guide them in exploring the website. Most participants noted that they would expect the home page to provide links to the latest safety case study or training information. As this was an early prototype, a number of areas of the screen were left blank (e.g. placeholders for graphics or text). All participants suggested that some of these might include images which might link to particular content in the different website sections.

Figures 8, 9, 10 and 11 illustrate the Application Summary Screen for the four different applications – namely (1) the Personal – not logged in application, (2) the Personal – logged in application, (3) the Dispatch application and (4) the EFB application.

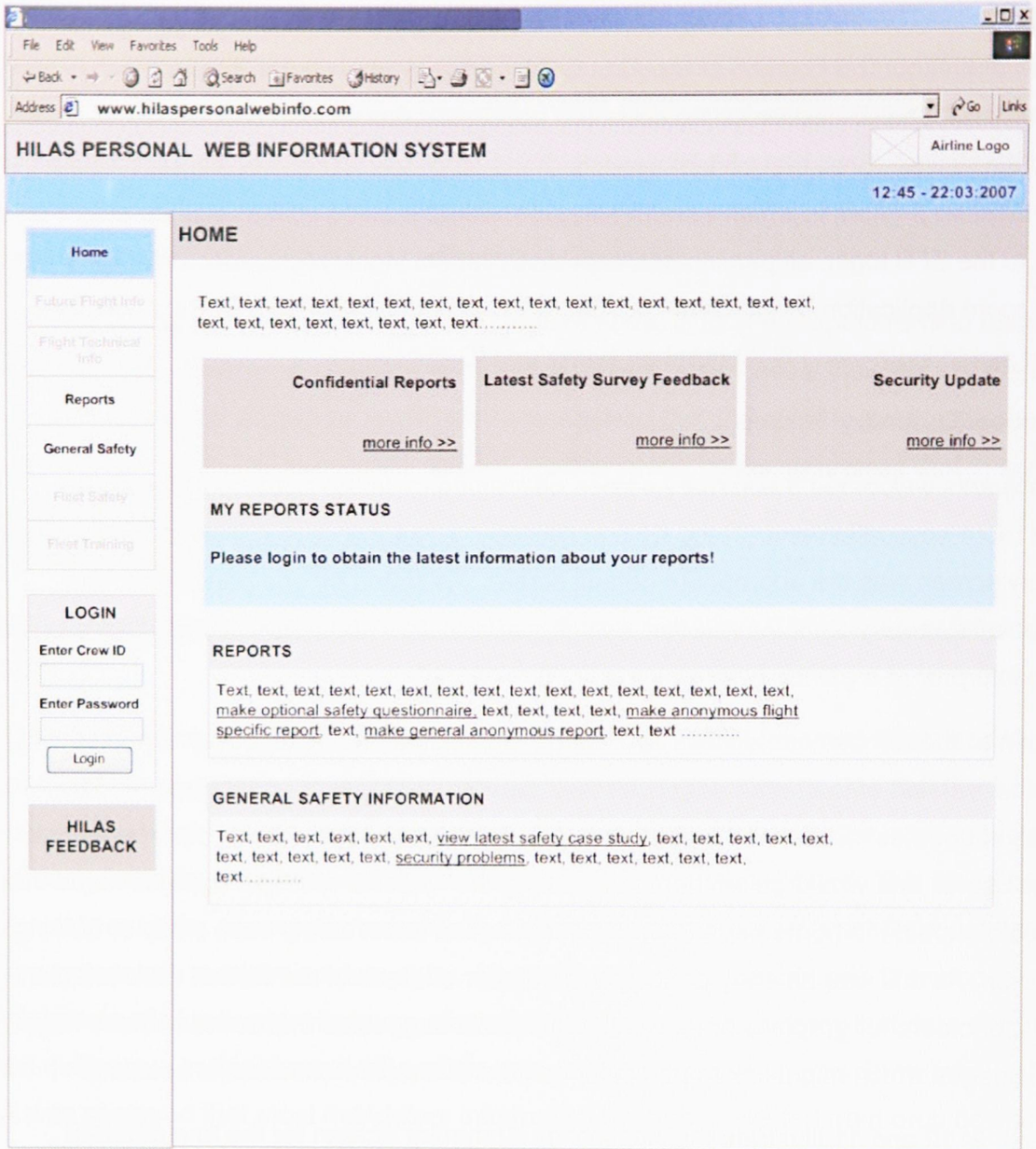

Figure 8: Personal - Not Logged In Application, Home Page (Study 5)

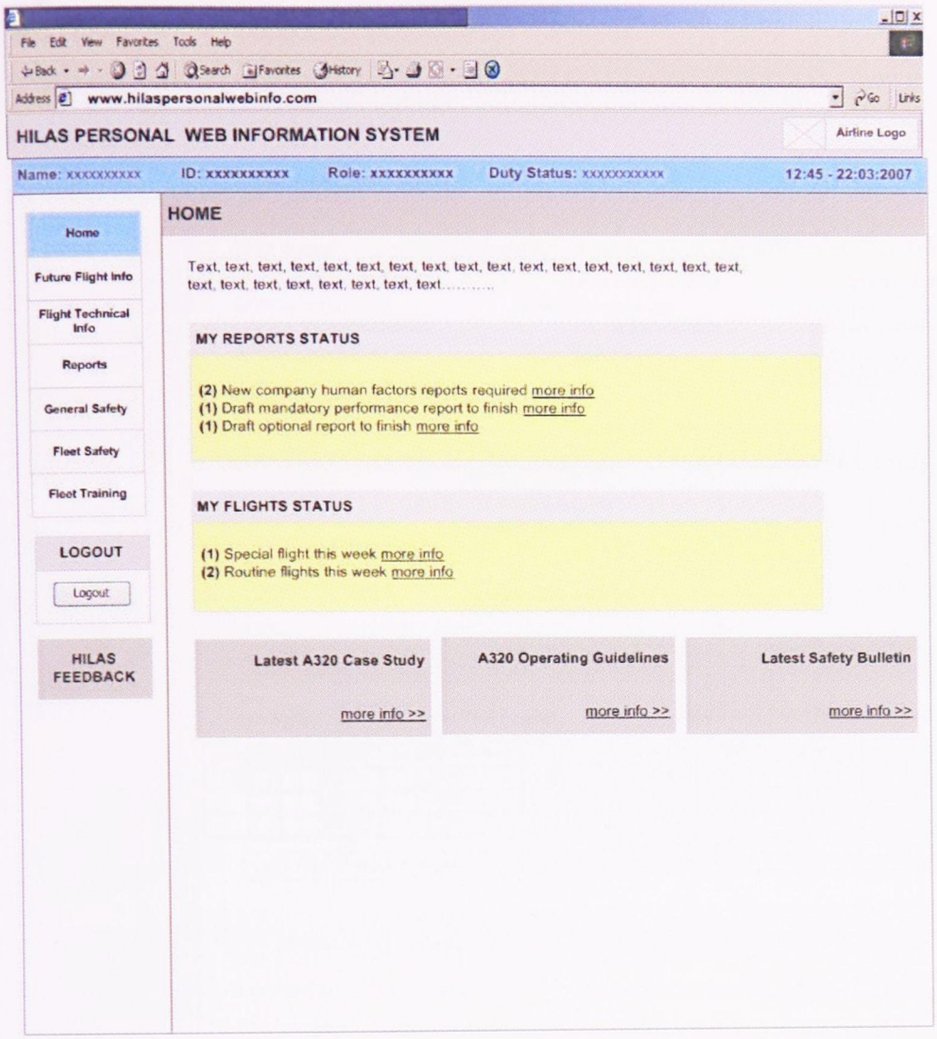

Figure 9: Personal Application – Logged In, Home Page (Study 5)

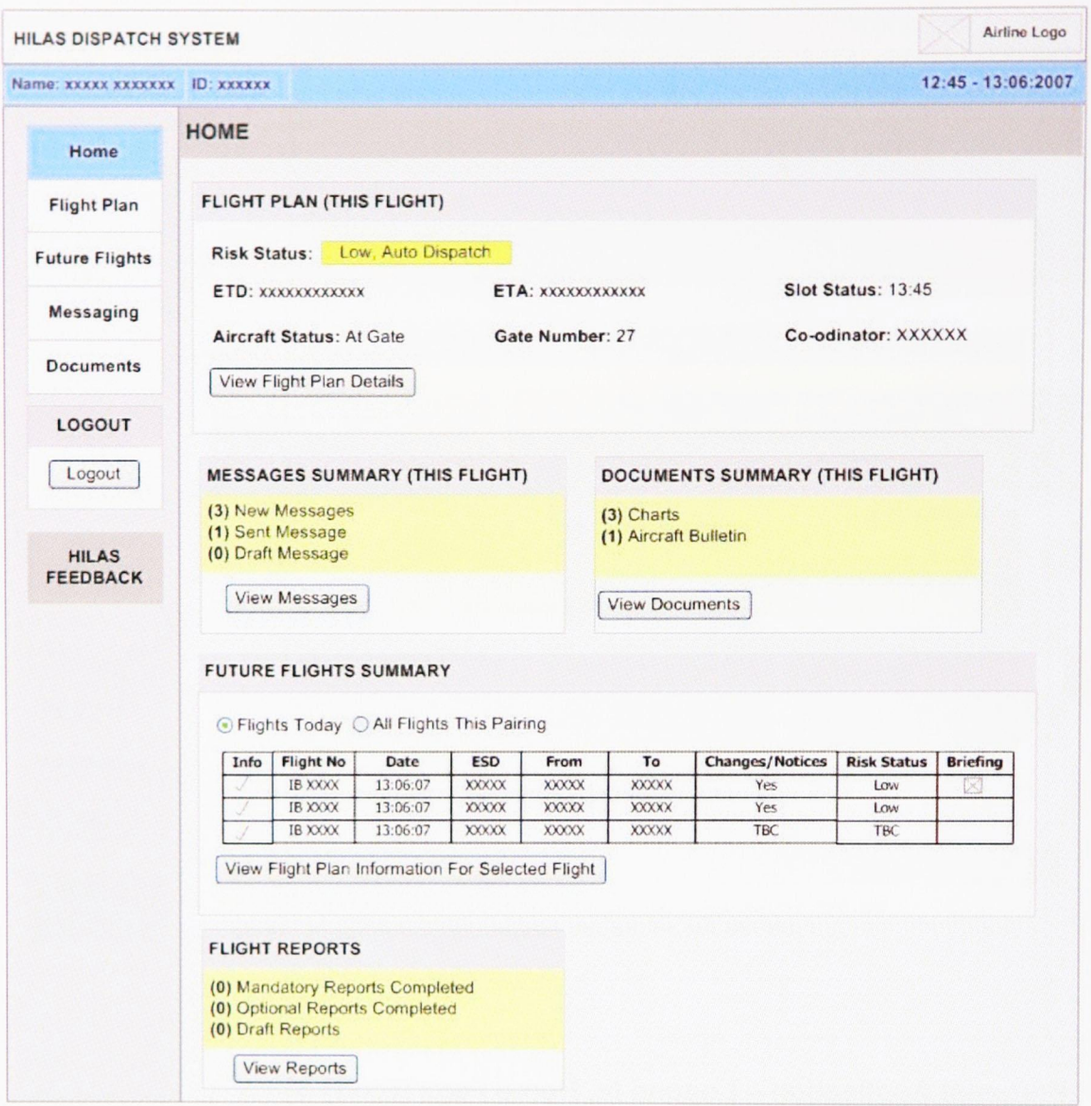

Figure 10: Dispatch Application, Home Page (Study 5)

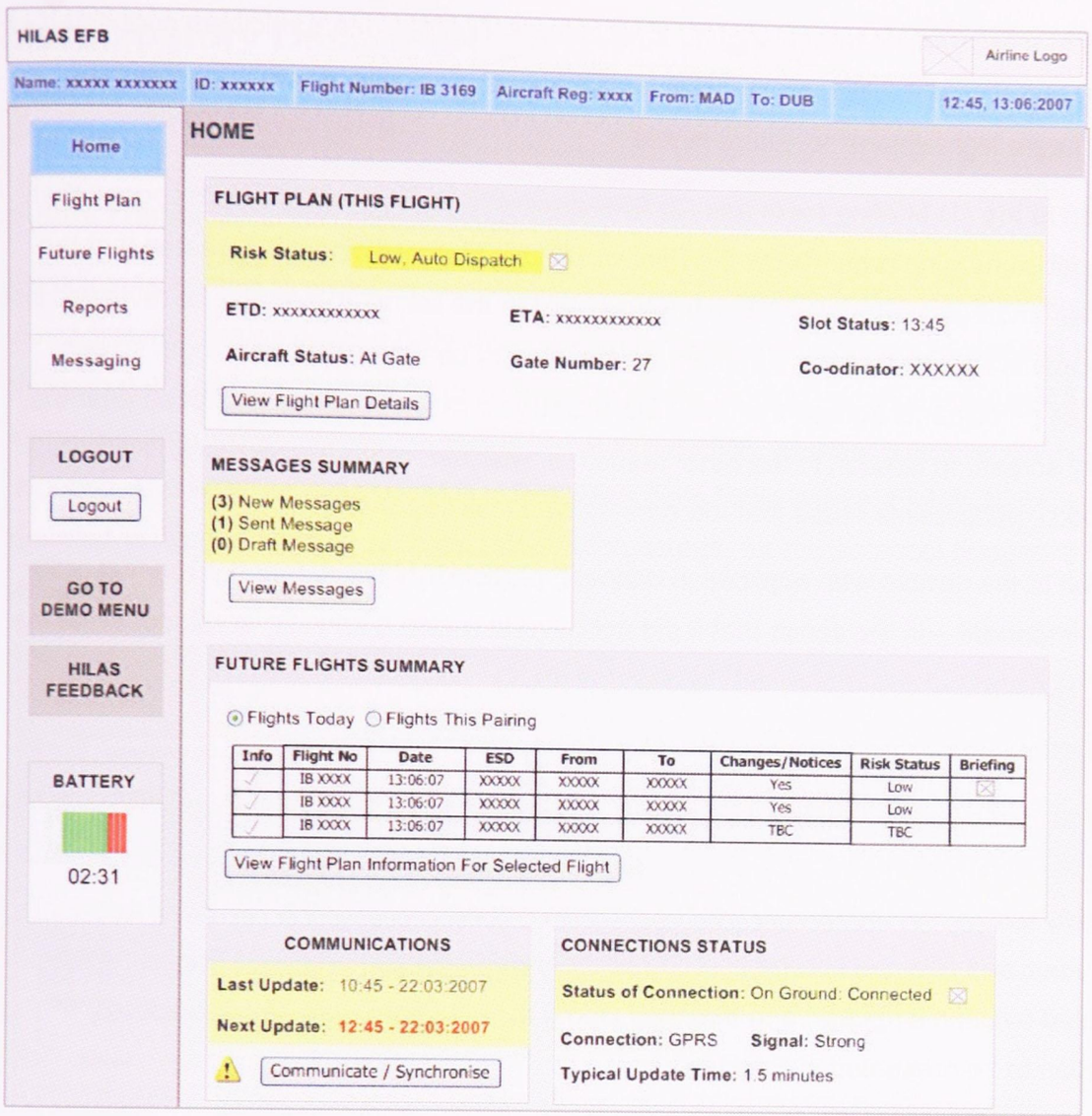

Figure 11: EFB Application, Home Page (Study 5)

Information Design/Layout

All participants observed that specific screens should not feature too much information. For specific application sections, participants noted the importance of presenting summary pictures and allowing users to drill down deeper into information, if this was required. Further, all participants emphasized the requirement to present information is an appropriate visual format, so that key information can be distinguished from less important information. In relation to all three application concepts, participants stressed the importance of clearly communicating what is mandatory and what is optional. Four participants observed that they would expect the three different applications to have broadly the same look and feel.

Navigation

All participants found the navigation intuitive and clear. Further, participants understood that the highlight on a specific navigation menu item indicated user location. Three participants noted that some of the navigation terminology might need to be changed, to match the airline terminology. It was noted that it is best to use the language of the specific airline, as

opposed to more generic terminology to fit all airlines. Further, one participant suggested changing certain terminology on the EFB application. Specifically, it was suggested to change 'future flights/plans' to 'future flights'.

In relation to the (1) briefing room and (2) EFB applications, one participant proposed that the navigation running order follow the Pilot workload. This participant suggested that the Flight Plan and Fuel information should feature last in the list, as this would be reviewed last. All participants agreed that the summary screen should be the default post login screen. Further, all participants agreed that the TEM/briefing section should be displayed after the summary screen. In relation to the other items (i.e. weather, aircraft, crew, load, NOTAMS and airport), participants noted that the running was less important.

In relation to the remote web application concept, participants noted that the running order was not important – in the sense that it did not have to match a specific workload. What the user might do would depend on their requirements.

Localisation

Four participants suggested that the content on each of the applications should be written in the local language of the airline (i.e. Spanish). Two participants stated that this was specifically relevant to the remote web application – specifically for the review of accident case studies and relevant information. Three other participants noted that English is the designated aviation language and that they would expect Flight Plan and associated information to be presented in English.

Summary Information

All participants understood the summary information on the top of the screen. Participants stated that on the remote web application this should refer to their user ID details. However, on the (1) crew briefing room application and (2) the EFB application, this should provide a summary of the specific flight details.

Section Context Summary

All participants understood the context summary on each relevant page.

List Function and Filters

Participants welcomed the list function with filters for viewing a sub-set of list contents. Participants noted that the list summary screen (for all functions) should include key information only, and that they would expect to select on a list option to obtain more detailed information. Participants noted that the list summary might include a mix of text and/or icons as appropriate. This would facilitate fast scanning of information and the identification of key list items, based on the user's task.

Participatory Design & Evaluation, Phase 2

Personal

Future Flights Summary/Home Page

Participants agreed to preserve the distinction between routine flights and special flights. It was agreed to assign special flight status to those flights that require an extended briefing or those that are generally rated more complex to fly. All participants requested that future flight summary information include the status of the information, whether a special briefing is included, and whether either crew had flown this flight route before. Figure 12 depicts the updated version of the Future Flight Information screen, for the personal (logged in) application.

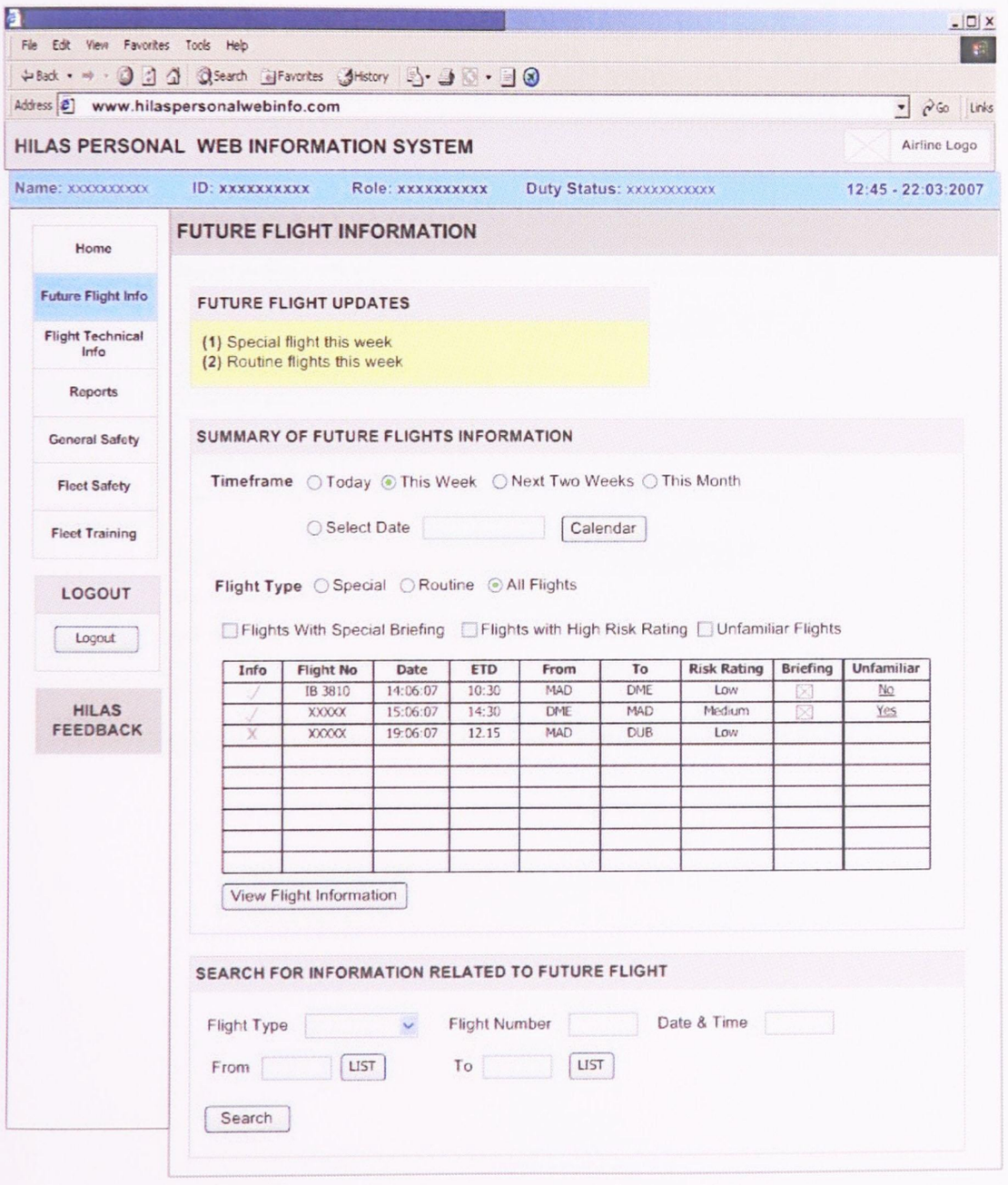

Figure 12: Personal Application - Logged in, Future Flights (Study 5)

Dispatch

Home

Participants responded positively to the flight summary list. Specifically, participants welcomed the provision of an icon detailing the status of future flight information and also the risk rating for the flight. Participants observed that the icon for the risk rating should reflect the latest status of the flight. It was noted that this may change over time. For example, poor weather might change the risk status. Further, participants stated that the flight list should include information on whether the flight includes a special briefing.

Flight Plan (Current Flight): Flight Overview Information

Participants suggested that the flight overview screen should feature two panels, to distinguish departure and arrivals information. Participants remarked that the arrival information should include the CAT status of the aircraft, the current runway in use and weather information. Figure 13 illustrates the updated version of the Flight Plan Summary Screen, for the Dispatch application.

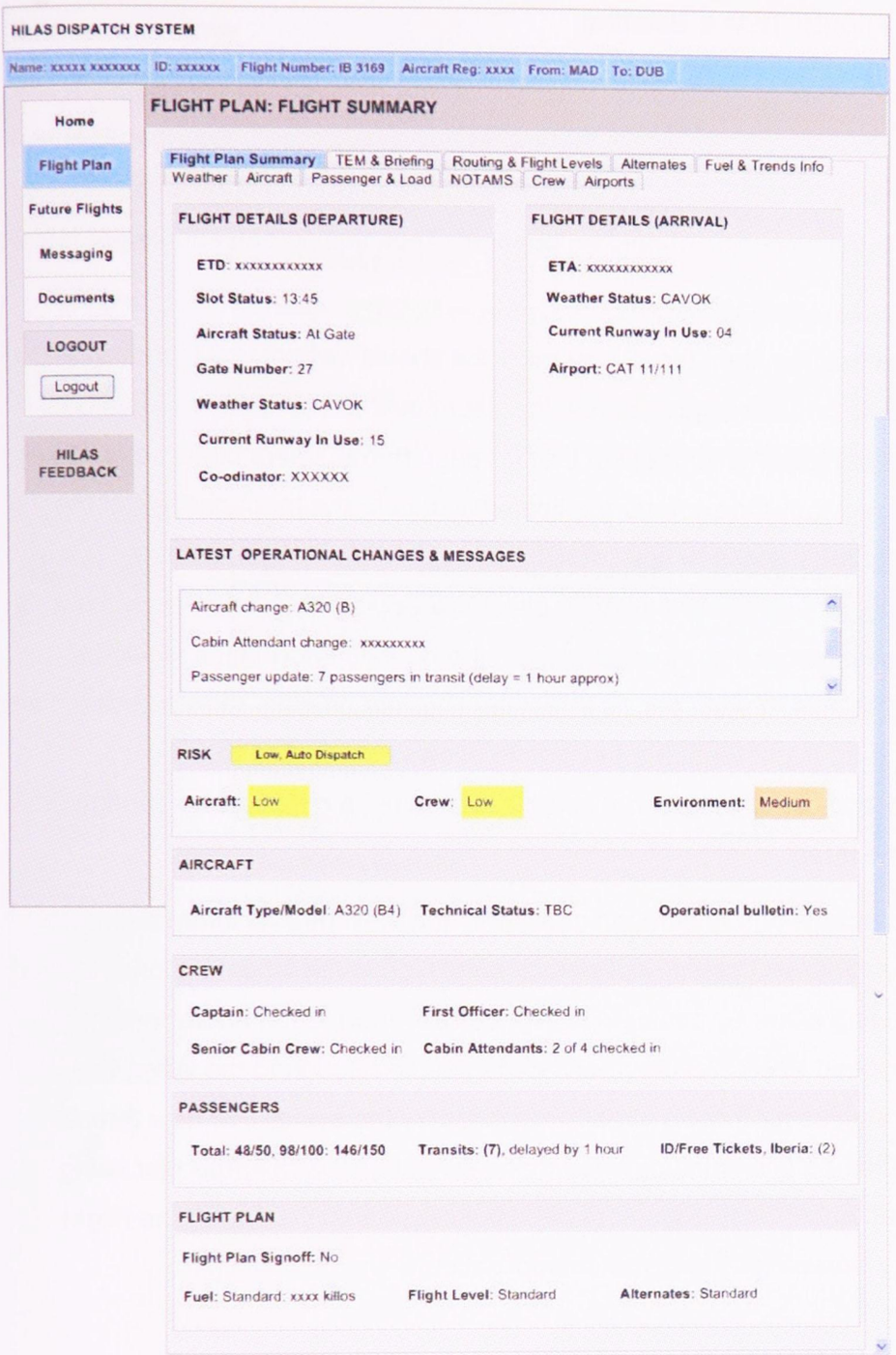

Figure 13: Dispatch Application, Flight Plan Summary (Study 5)

Flight Plan (Current Flight): TEM & Briefing

Participants suggested that this screen should support the briefing process and specifically communication in relation to the particular flight threats and associated threat management strategies. As such, this links to TEM and briefing practices explored in crew CRM training. All participants noted that this review should be optional. Thus this screen should not feature a signoff function.

Participants suggested that the flight threat summary list should default to all threats for that specific flight. Depending on user requirements, the user could filter this list according to different flight phases. Participants suggested that for each threat, users could select a link which would launch a pop up window featuring tips/advice as to the management of the threat. Further, it was noted that these tips could be populated from reports data. Participants also noted that users might select a checkbox positioned beside each threat, to add additional information about that threat. As such, the briefing information would be general, until the user selects to add specific threat items to the briefing. One participant also suggested that this screen might feature a function to allow users to add their own information. Two participants suggested that users might select a checkbox to confirm their intention to manage the threat.

Overall, there was a perception that although crews might review threats information, few would use the high involvement options. For participants, high involvement options referred to customizing the briefing either by adding new flight threat information and/or entering information about proposed threat management strategies. In relation to the latter, this includes proposed strategies for threats already identified by the system, or new threats entered by the crew. One participant suggested that crew should be rewarded for using advanced/high involvement options. Figure 14 depicts the updated version of the Flight Plan/TEM and Briefing Screen for the Dispatch application.

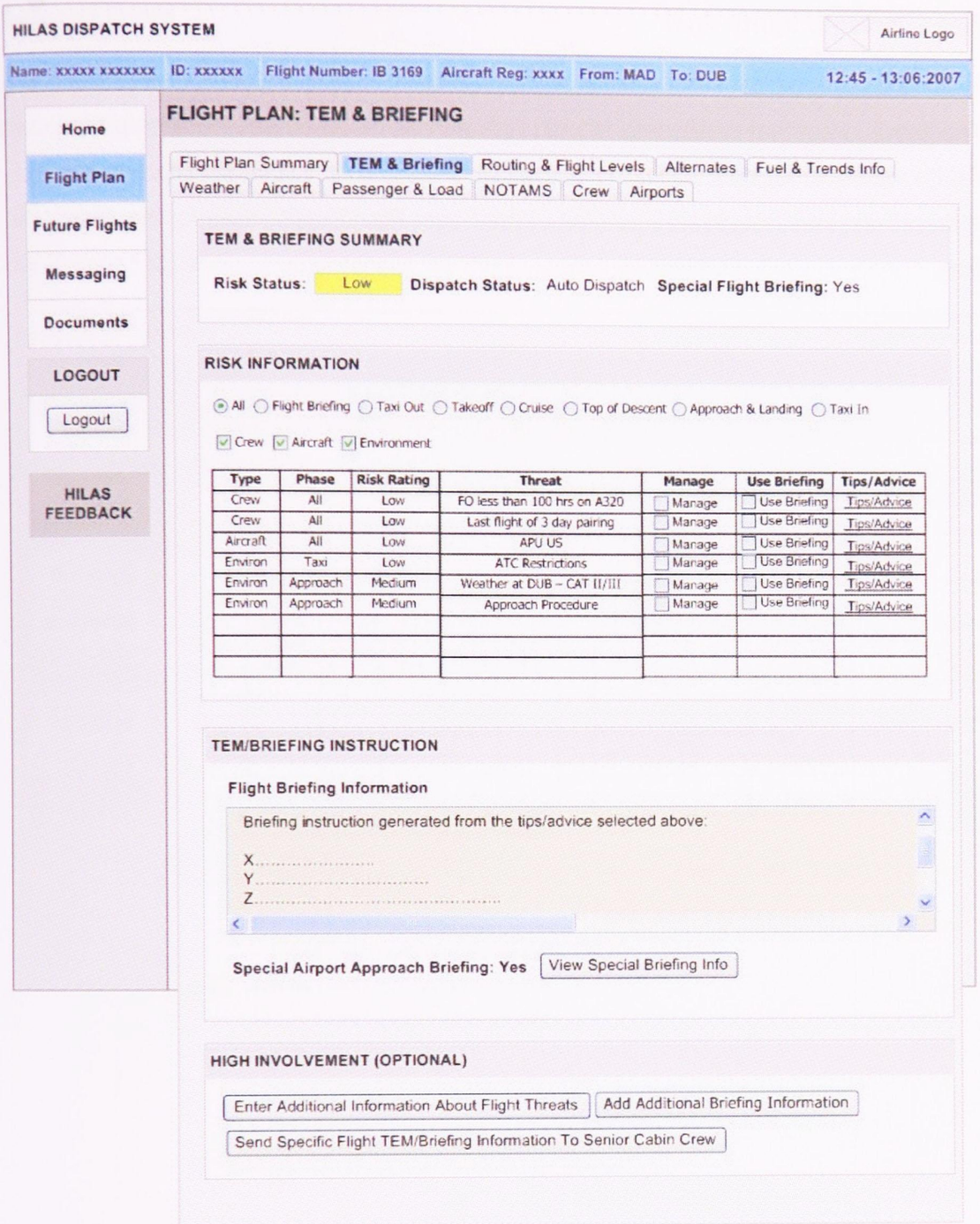

Figure 14: Dispatch Application, TEM & Briefing Screen (Study 5)

Flight Plan (Current Flight): Fuel

All participants suggested that this screen might provide a complete breakdown of the fuel figure. The provision of fuel trends information was perceived as useful. Further, participants noted that the ability to request additional fuel electronically would result in time savings for crew. Figure 15 depicts the updated version of the Flight Plan/Fuel screen for the Dispatch application.

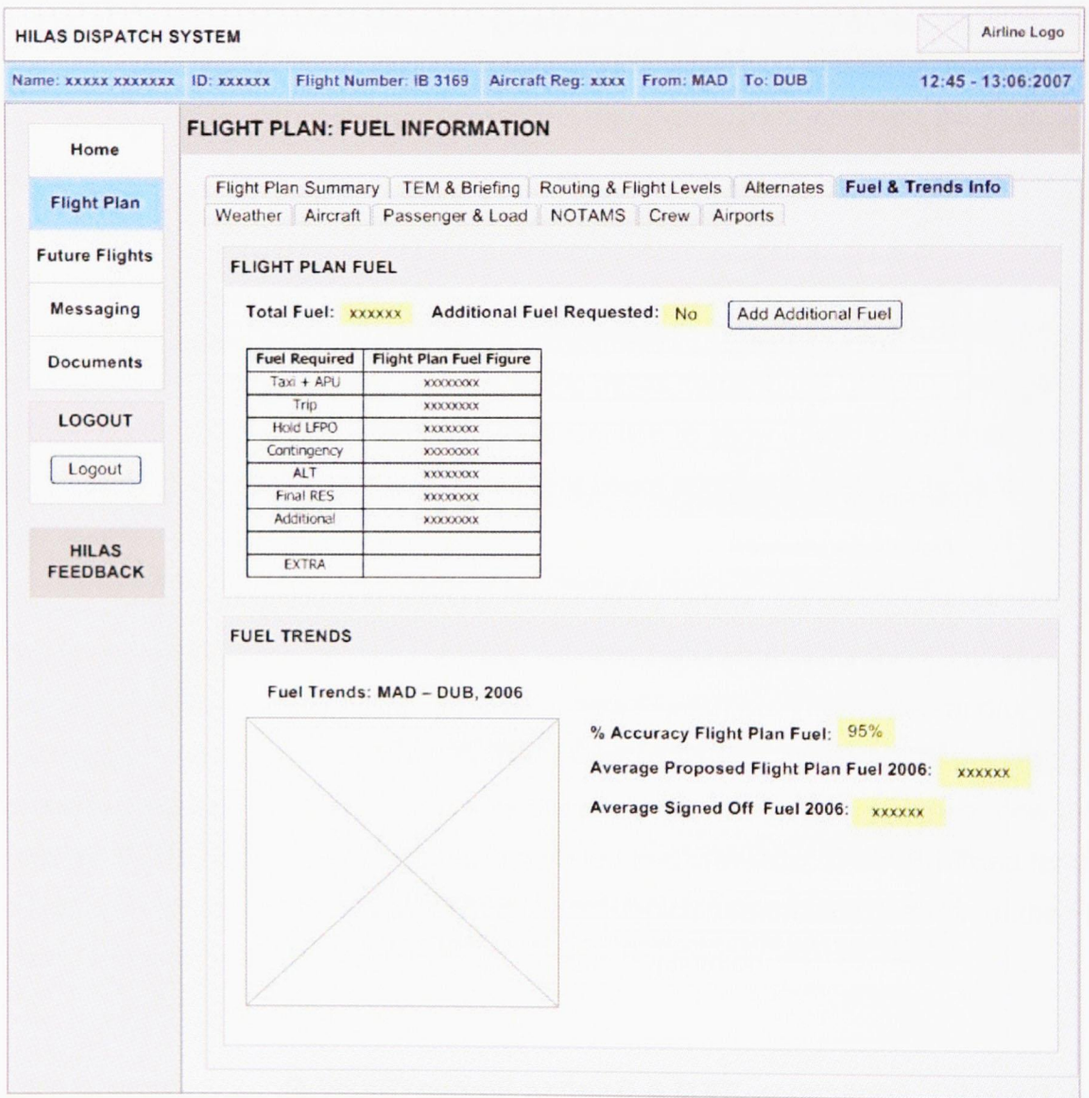

Figure 15: Dispatch Application, Flight Plan/Fuel Information (Study 5)

Future Flights

Participants suggested that an additional column be added on the future flights list to indicate the crew's familiarity/experience with the flight route. It was recommended that the flight planning system would contain this information. Participants stated that the risk profile rating and the briefing information indicator is useful. Figure 16 illustrates the updated version of the Future Flights Summary screen for the Dispatch application.

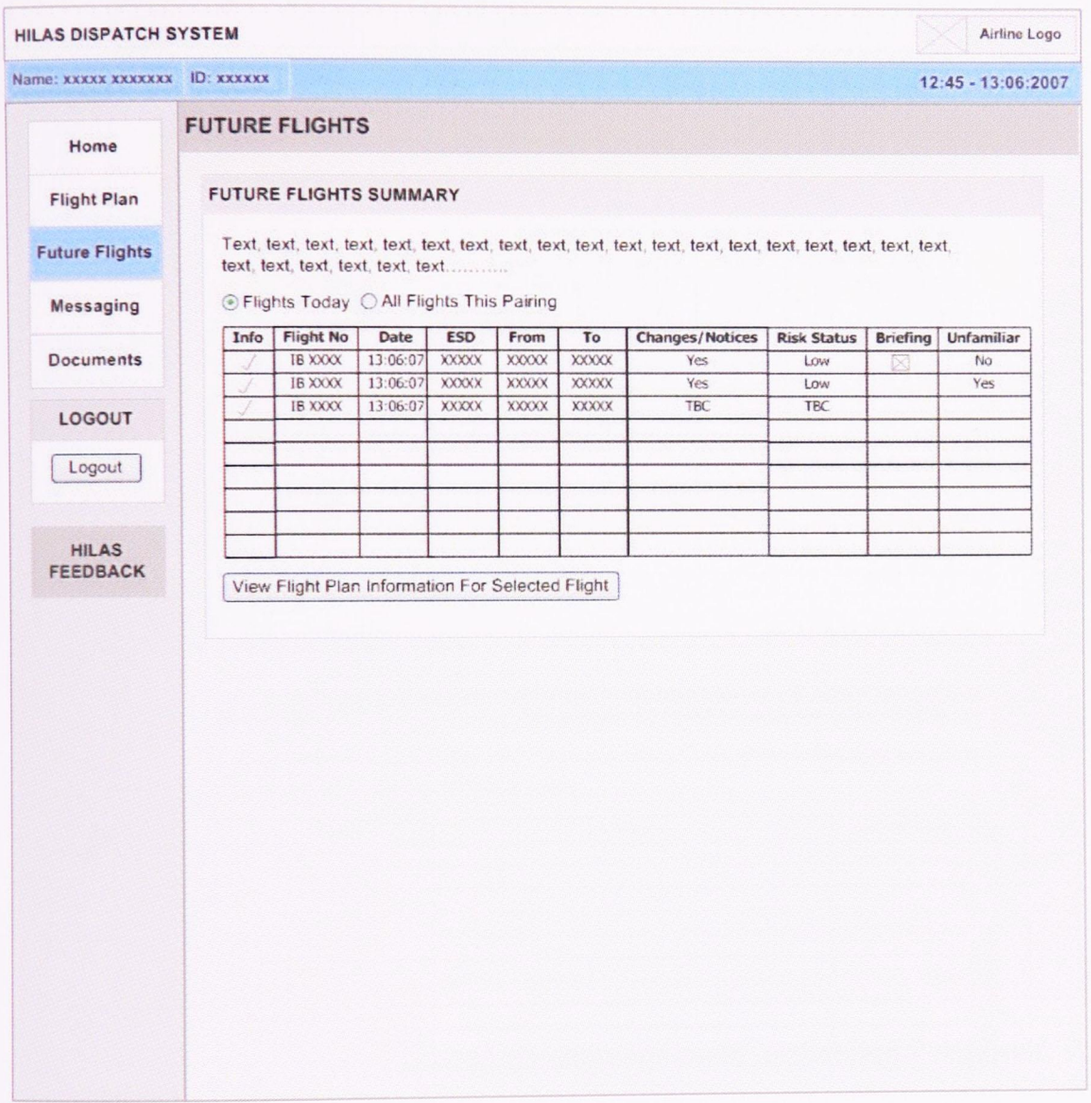

Figure 16: Dispatch Application, Future Flights (Study 5)

Messaging

Participants suggested that the message list be organised into three overall tabs. This includes received message, sent messages and draft messages. Figure 17 illustrates the updated version of the Messaging Summary screen for the Dispatch application.

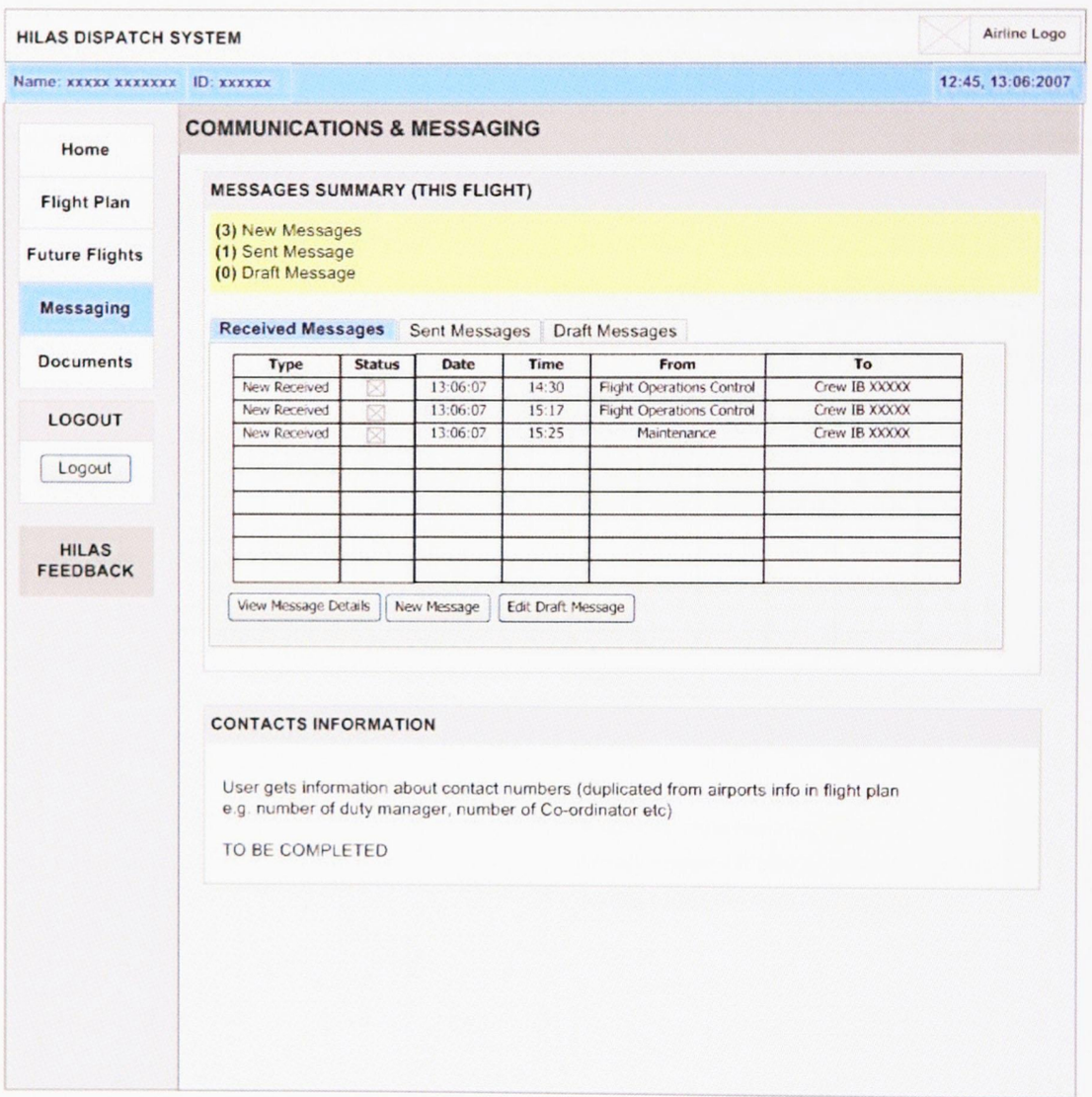

Figure 17: Dispatch Application, Messages (Study 5)

Documents

Participants stated that the ability to access flight specific document such as charts and aircraft operational bulletins, in electronic format would result in time savings for crew. Participants were undecided as to whether crews should be able to access any document at this point, or just flight specific documents. Figure 18 represents the updated version of the Documents Summary screen for the Dispatch application.

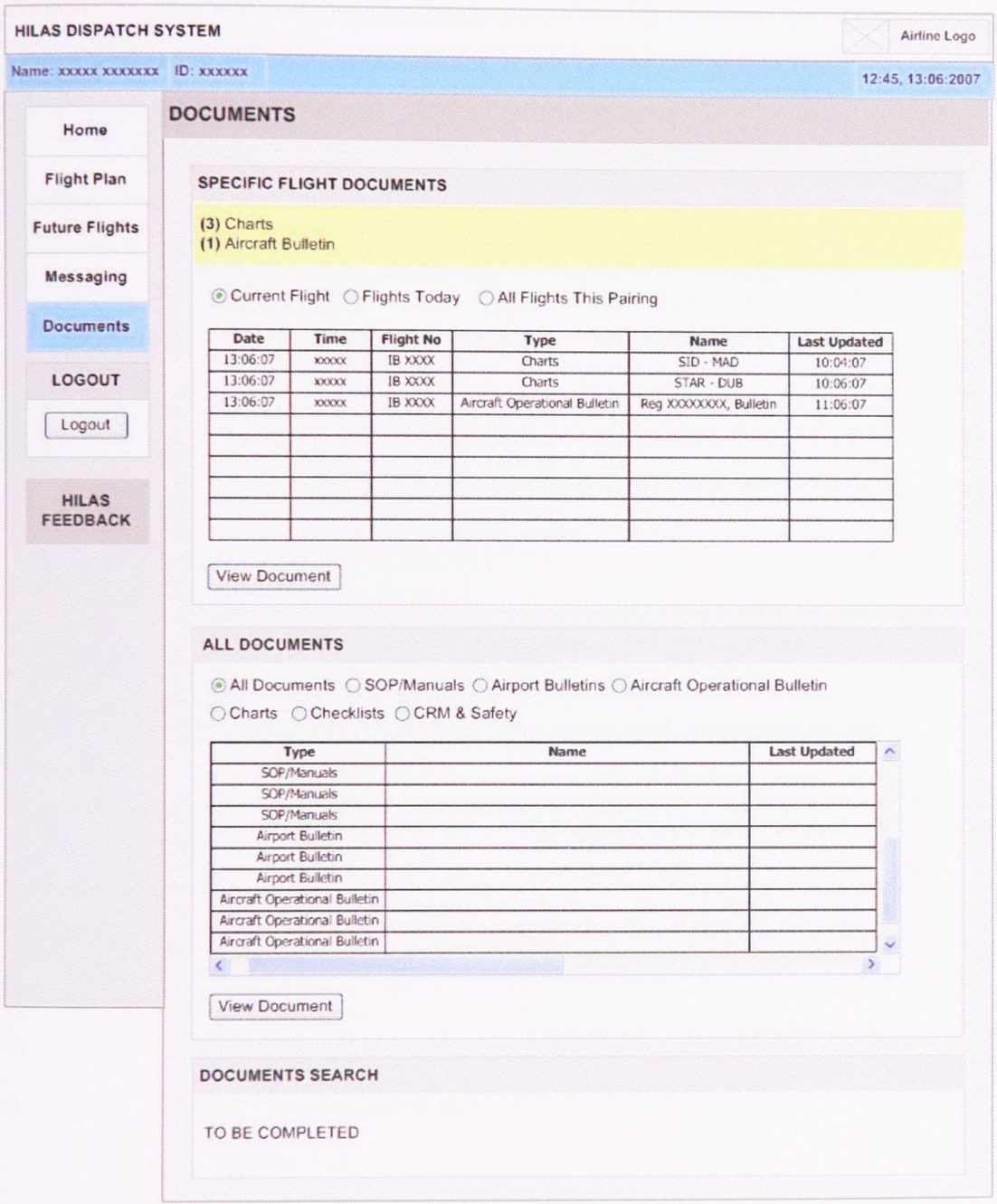

Figure 18: Dispatch Application, Documents (Study 5)

EFB

Login

Participants suggested that the login screen should instruct users that either crew can login (i.e. not just the Captain).

Flight Plan: Next Flight or Other Flights That Day

Participants noted that the workflow should draw a distinction between the active Flight Plan and the future Flight Plan. It was suggested that users should not be able to perform actions related to future flight plans, until the most recent flight plan has closed. For example, during flight, crews should be able to view fuel information for the next flight, but not request additional fuel. Additional fuel can only be requested, once the flight plan is active. Further, participants noted that the future flight information should include an instruction to users to synchronise the EFB, once on the ground, to ensure they are viewing the most up to date information. Figure 19 depicts the updated version of the Future Flights Summary screen for the EFB application.

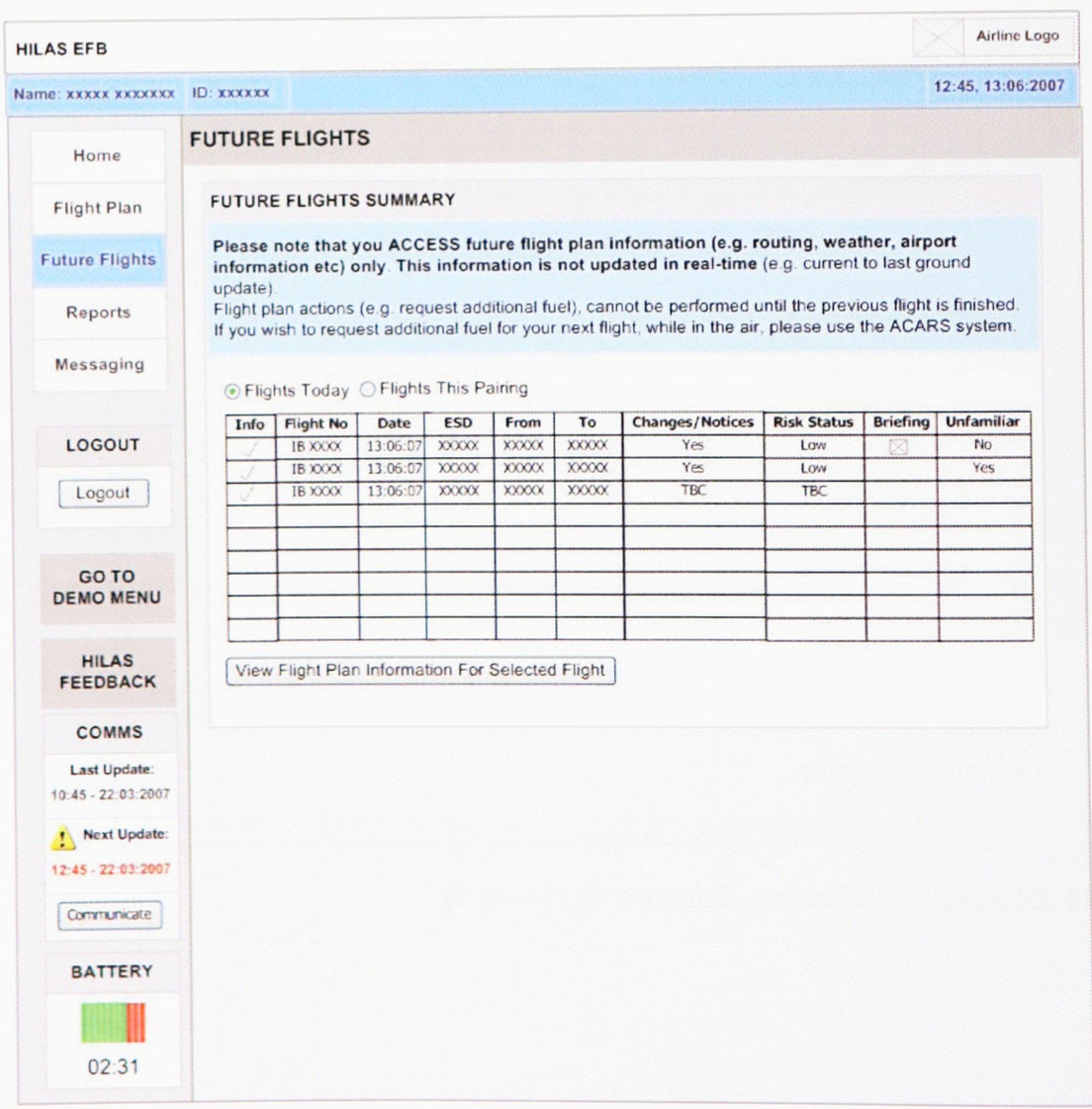

Figure 19: EFB Application, Future Flights (Study 5)

Communications

Participants noted that the system should remind users of the requirement to synchronise the EFB system with ground systems when on ground, to ensure the latest information is sent and received. Further, the system should remind users that new messages composed in air are not sent until the user synchronises the EFB when on the ground. Figure 20 illustrates the updated version of the Communications Summary screen for the EFB application.

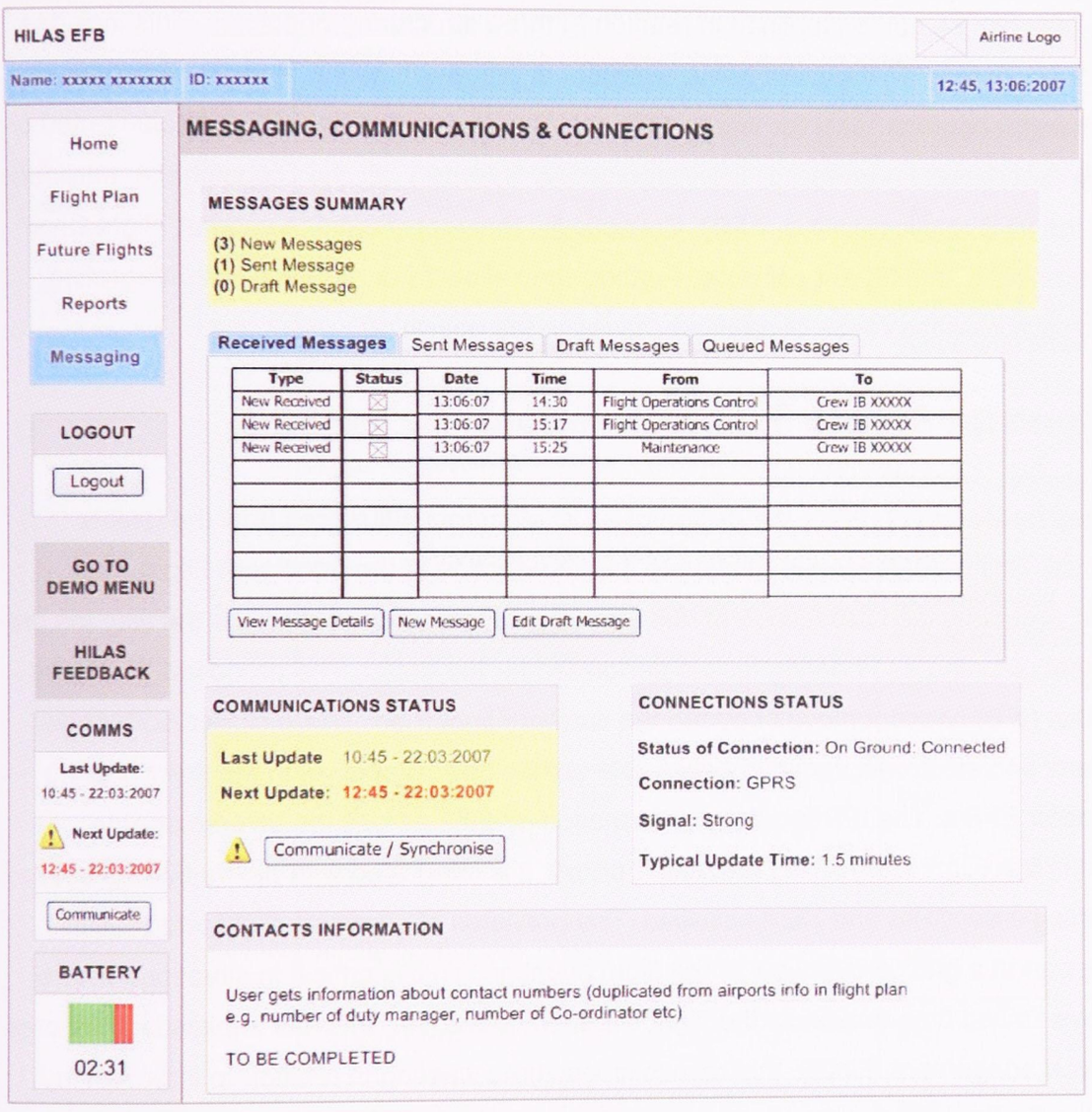

Figure 20: EFB Application, Messaging (Study 5)

4. DISCUSSION

IFP: Cockpit and Not Cockpit Concepts

In introducing new Flight Crew tools, researchers should not focus on cockpit tools alone. Rather, Flight Crew tool requirements must be considered in a more holistic sense. As demonstrated, Flight Crew tool requirements supporting the pre flight, flight planning and briefing task can be conceptualised in relation to three structuring principles. This includes: (1) the duty context, (2) the point in the operational process/timeline, and (3) crew location. This generates requirements for three versions of an electronic Flight Plan, implemented on three platform types - namely: (1) the Personal (i.e. Internet), (2) the Dispatch (i.e. Intranet) and (3) the EFB application (i.e. EFB). Collectively, these applications support Flight Crew pre-flight briefing, in different contexts. Further, they allow for a mobile office, integrating information across the range of agents involved in the operation.

IFP Concept & Task Transformation

As argued by Norman (1988), the design of an artefact/tool influences how the task is performed. This is evidenced in relation to the introduction of the Intelligent Flight Plan concept. Arguably, the introduction of this new Flight Plan concept changes the way the pre-flight, flight planning and briefing task is performed for the better. The proposed Intelligent Flight Plan (IFP) concept moves beyond the current Flight Plan. This includes both paper flight plans and electronic versions accessible on desktop computers in the crew briefing room and/or EFB's. The IFP facilitates information sharing across the diverse agents involved in the Flight Operations process. Further, it is integrated with airline SMS processes - supporting crew CRM and TEM activities. The provision of summary flight information facilitates an at a glance overview of the flight situation. This is critical in situations where crew have limited time to assess the flight situation. Moreover, this has implications for crew workload management. Firstly, this results in less time wasting in relation to information searching. Further, the provision of upfront information about threats (both actual and potential) ensures that crew are briefed and in a better position to manage both the problem and the increase in workload, if such threats emerge in the actual operation. Moreover, the provision of information about crew threats and more general TEM information serves as prompt for crew TEM activities, and in particular, for the necessity to foster a robust team concept. Overall, such improvements in information access and availability enhance crew situation awareness, teamwork and workload management. A comparison of the existing Fight Plan and the proposed Intelligent Flight Plan is provided in Table 31 below.

Table 31: Comparison of Existing Flight Plan and Intelligent Flight Plan (Study 5)

Category	Subcategory	Current Flight Plan	Intelligent Flight Plan
Medium/format	-	Paper or Electronic	Electronic
Where Access	-	Crew Room Aircraft	Crew Room Aircraft Remote (aircraft or hotel)
Tools use to access	-	Desktop computer ACARS	Desktop computer Electronic Flight Bag
Functionality	Support different briefing contexts	No	Yes Supports briefing for (1) current flight, (2) next flight and (3) future flights.
	Provide access to flight plan information	Yes	Yes However, provides more detailed information in relation to aircraft technical status, crew details, routing/alternates information and fuel figure information.
	Send/receive operational and safety updates	No	Yes
	Risk Assessment	No	Yes
	Support CRM/TEM	No	Yes
	High Involvement: CRM/TEM	No	Yes
	Flight Plan signoff	Yes	Yes
Core Information Provided	Summary overview of Flight	No	Yes
	Risk Assessment of Flight	No	Yes

	TEM	No	Yes
	Briefings/CRM	No	Yes
	Routing	Yes	Yes, but more detailed
	Weather	Yes	Yes, but more detailed
	Fuel	Yes	Yes, but more detailed
	Aircraft	Yes	Yes, but more detailed
	NOTAMS	Yes	Yes, but more detailed
	Crew	Yes	Yes, but more detailed

The advantage of the IFP approach rests in the use of both operational and safety data to support the design of appropriate flight plans (i.e. assisting the work of both Flight Planning and Dispatch), the identification of high risk flights and associated go/no go decisions, crew teamwork and specific team situation assessment activities. This approach represents an extension of the existing state of the art. As shown, the IFP for the current flight provides an overall flight risk assessment, taking into account three different categories of risks - crew, aircraft and environment. As such, this extends this research of Dutcher (2009), in relation to the management of weather based hazards in flight operations. Weather can be conceived as a subset of the risk information provided in the environment category. Moreover, this approach links to the risk management concepts proposed by Loukopoulos (2009), albeit the context (i.e. commercial operations) and Flight Crew role is different. In the concept proposed by Loukopoulos (2009), Pilots have responsibility in relation to making the risk assessment. In the proposed IFP concept, although the Captain is in charge, this is a collaborative task. As such, the Captain is conferring with the First Officer, along with taking into account the guidance provided in the IFP and feedback from Dispatch/Flight Operations Control (i.e. if high risk flight). Lastly, the IFP concept is inspired by several recent research developments linking to the free flight concept (Johnson, Battiste and Bochow, 1999), and the SESAR research programme (Derisson, 2007). Specifically, this refers to the objective of integrating information flow across all relevant stakeholders, to support Flight Crew 4 D trajectory management and separation responsibility in specific airspace sectors. The IFP is designed from the perspective of the current operational concept (i.e. fixed routes and ATC managerial role for separation), and associated airline Flight Planning functions. In this case, the focus is sharing information across specific airline stakeholders (i.e. Flight Operations and Maintenance), to support a safe and efficient operation. Potentially, the IFP concept might be extended to include information sharing with ATC, as part of a future free flight implementation.

Embedding CRM/TEM Concepts in Flight Crew Tools

CRM and TEM concepts are more than abstract principles to be deployed by Pilots during the operation. These training frameworks illuminate the specific human factors requirements of collaborative work situations (i.e. team work, shared understanding of process and information communication), and as such generate high level requirements for improved tools. This has been taken into account in terms of the development of the IFP concept. The IFP concept supports information sharing between different roles. This in turn fosters teamwork both within the cockpit, and between the cockpit and other operational roles. Moreover, the IFP provides specific task support for crew TEM activities. This serves two functions. Firstly, it encourages Flight Crew to incorporate TEM activities within their briefing. Secondly, it provides specific information support for TEM activities. It is anticipated that this will improve the quality of crew briefings. This in turn may yield flight safety improvements.

5. CONCLUSIONS

With the exception of what is happening locally at airlines, research has not addressed Flight Crew issues at the pre-flight, flight planning and briefing stage. In particular, Flight Deck research has not tackled Flight Crew problems with the design of the existing Flight Plan. The introduction of the Intelligent Flight Plan concept therefore represents an attempt to resolve these issues.

The proposed risk based Intelligent Flight Plan concept moves beyond the current Flight Plan. This includes both paper Flight Plans and electronic versions accessible on desktop computers in the crew briefing room and/or EFBs. The Intelligent Flight Plan facilitates information sharing across the diverse agents involved in the Flight Operations process. As the Flight Plan is accessible from anywhere (i.e. cockpit, remote access and crew room), it supports flight planning and associated information management activities, at different points in the operational timeline and in different contexts. Further, it is integrated with airline SMS processes. Overall, this helps solve certain process and task problems related to the sharing of operational and safety information across team agents. Moreover, the proposed IFP concept features new information and task support functionality linked to Crew Resource Management (CRM) and Threat and Error Management (TEM) activities. In this way, this research demonstrates that CRM and TEM theory and associated training approaches can be usefully embedded in the design of improved Flight Crew tools, and specifically the Flight Plan. Here we can directly link human factors theory to the design of improved Flight Crew tools.

Three versions of the Flight Plan have been advanced (i.e. current flight, next flight or other flights that day, and future flights). These are preliminary HCI concepts and require further

elucidation. Moreover, much of this research was conducted with one Pilot. Thus, the proposed HCI concept requires validation with additional Pilots. This is explored in Study 6.

The introduction of the IFP necessitates the advancement of new operational and organisational processes and tools, supporting information flow within the airline, and specifically the intelligent use of performance/safety data. To date, the specification of these processes has been Pilot led. In advancing the Intelligent Flight Plan concept, certain assumptions have been made about how these underlying processes might potentially work (i.e. the analysis of TEM information for a specific flight by Safety Personnel). These processes must be specified and validated with relevant stakeholders (i.e. Flight Planning, Dispatch, Flight Operations Control and Safety). The introduction of the proposed Intelligent Flight Plan may be beneficial in terms of the projected impact on Flight Crew situation awareness, teamwork and workload. However the work effort to support the processes underpinning the Intelligent Flight Plan may be too great. In this sense, the feasibility of specific Intelligent Flight Plan concept must be ascertained. Moreover, additional research is required with airline IT personnel, to understand the broader systems requirements related to the introduction of this tool. Collectively, these issues are examined in Study 6.

Study 6: Advancement of Intelligent Flight Plan HCI Concept for the Current Flight, and the Underlying Process Requirements

1. CHAPTER INTRODUCTION

This chapter reports on the sixth HILAS study. This study focuses on the advancement of the initial HCI concept for the current flight only, along with the specification of the underlying process necessary the implementation of this concept. Two participatory sessions were conducted with one Pilot from Airline 5. This was followed by an implementation workshop involving ten participants from Airline 5.

2. RESEARCH DESIGN

Objectives

The objective of this study was to further specify the HCI concept for the Intelligent Flight Plan, and to scope the requisite operational and organisational processes necessary to the implementation of this concept at the airline.

Method

First Participatory Design and Evaluation Session

The first session involved the participation of one Pilot. In this session, the Researcher and the Pilot jointly reviewed the proposed Intelligent Flight Plan user interface screens for the current flight only. As part of this, the Researcher and the Pilot analysed and agreed particular improvements to the existing HCI concept. Also, certain functions which were previously undefined and/or only partially defined were further specified. Following this, the Researcher and the Pilot commenced the initial high level specification of the underlying operational and organisational processes necessary to the implementation of the Intelligent Flight Plan concept at the airline. In so doing, the Researcher and the Pilot focussed on a subset of Intelligent Flight Plan functions. This included: (1) the generation of a risk rating for the flight, (2) the provision of detailed TEM information in relation to each of the risk categories (i.e. crew, aircraft and environment) and (3) the generation of additional briefing information. In relation to each of these functions, the Pilot and the Researcher outlined the

particular processes and functions involved, the task workflows of these different functions and the associated information sharing requirements. Further, the Researcher and the Pilot outlined the overall information flow requirements in relation to the proposed HILAS system and associated tool concepts (i.e. Tools A, B and C). The emerging process requirements were recorded in a word document.

Updates to Prototypes 1 and Process/Scenarios Specification

Following the first session, the Researcher updated the prototypes. The CD accompanying this thesis features an example of these prototypes. Further, the Researcher updated the process descriptions documentation.

Second Participatory Design and Evaluation Session

A second session was then conducted with the same Pilot. First the prototypes were reviewed and further specified, using the same approach undertaken in the first session. Following this, the Researcher and the Pilot jointly reviewed the relevant underlying process descriptions supporting certain core Intelligent Flight Plan functions, and further elaborated on these descriptions.

Updates to Prototypes 2 & Process/Scenarios Specification

Following the second session, the Researcher further updated the prototypes and the allied process specification documentation. The CD accompanying this thesis features an example of these prototypes.

Implementation Workshop

As part of the collaborative prototyping and evaluation activities, the Researcher and the Pilot specified at a high level certain new airline operational and organisational processes necessary to the implementation of the Intelligent Flight Plan. Assumptions were made about the future work practices of other relevant agents (i.e. Flight Planning, Dispatch and Safety). Further, assumptions were made about the advancement of certain new systems, supporting the integration and analysis of airline safety information, and the communication of this information to relevant operational roles. This links in part to broader work conducted by other researchers in the HILAS project. In particular, this concerns the specification of new tools facilitating the integration and analysis of relevant performance and safety data, to facilitate both proactive and reactive risk assessments. As shown, these process descriptions were provisional. Consultation and validation with broader stakeholders is necessary. In this regard, the implementation workshops were used to define these processes and to assess the feasibility of proposed tool concept, in terms of organisational capacity, IT requirements and process design.

Prior to the workshop, the Researcher prepared a series of presentations, to explain the overall project background, the overall HILAS tools concept and the specific Flight Plan concept. A workbook was created which included background information about the IFP concept, specific user interface screen examples, and a series of process scenarios describing the relevant Flight Operations processes required to implement the different Intelligent Flight Plan functions. A copy of the presentations, the workbook, the process scenario descriptions and the HCI prototypes is provided in the CD accompanying this thesis.

A total of ten participants attended the workshop, four of whom were Pilots. The other participants included one representative from Flight Planning, two Dispatchers, one representative from Safety and two members of the airline's IT department. Overall, the workshop involved a scenario based design and evaluation approach. First, the project background and objectives was outlined. The background to the IFP concept was then explained. Following this, a mid-fidelity HCI prototype for the proposed Intelligent Flight Plan was presented. The overall concept and the specific HCI concept for individual screens were reviewed. Participants were then invited to assess the usability of the HCI and suggest re-design requirements.

The underlying process scenarios were then reviewed. Specifically, the Researcher read out the individual process scenarios, as detailed in the workbook. As part of this, the Researcher referred to the Intelligent Flight Plan prototype to demonstrate the link between specific user interface functions and the task requirements of other agents. Participants were then invited to comment on the process scenario, and in particular, to further specify the workflow requirement from their perspective. The Researcher then led a discussion about underlying IT requirements. This involved a discussion of issues related to the integration of Flight Crew/Dispatch tools with other airline systems, and the requirements for new systems to support certain new information sharing functions between Flight Crew and other roles.

Updates to Prototypes 3 and Process/Scenarios Specification

Feedback from the different sessions was then reviewed and evaluated. Following this, the prototypes were updated and the process scenarios were further defined. The Researcher also documented the broader technology requirements, in relation to the overall HILAS system.

Participants

This study involved the participation of ten participants. It should be noted that the same First Officer was involved in the two participatory sessions. Further, this First Officer attended the implementation workshop. A breakdown of participants is provided in Table 32 below.

Table 32: Breakdown of Participants (Study 6)

Phase	Participant Number	Role
PD 1	1	First Officer / CRM Trainer
PD 2	1	First Officer / CRM Trainer (Same as previous)
Implementation Workshop	1	First Officer / CRM Trainer (Same as previous)
	2	First Officer
	3	First Officer
	4	Captain
	5	Safety
	6	Dispatch
	7	Dispatch
	8	Flight Planning
	9	IT Representative
	10	IT Representative

3. RESULTS

Participatory Sessions (1 and 2)

User Interface Concept

Flight Summary Screen

As depicted in Figure 21, it was suggested that the flight summary screen should provide quick access to important briefing information, in addition to CRM briefing information. This includes access to operational bulletins and special approach briefings.

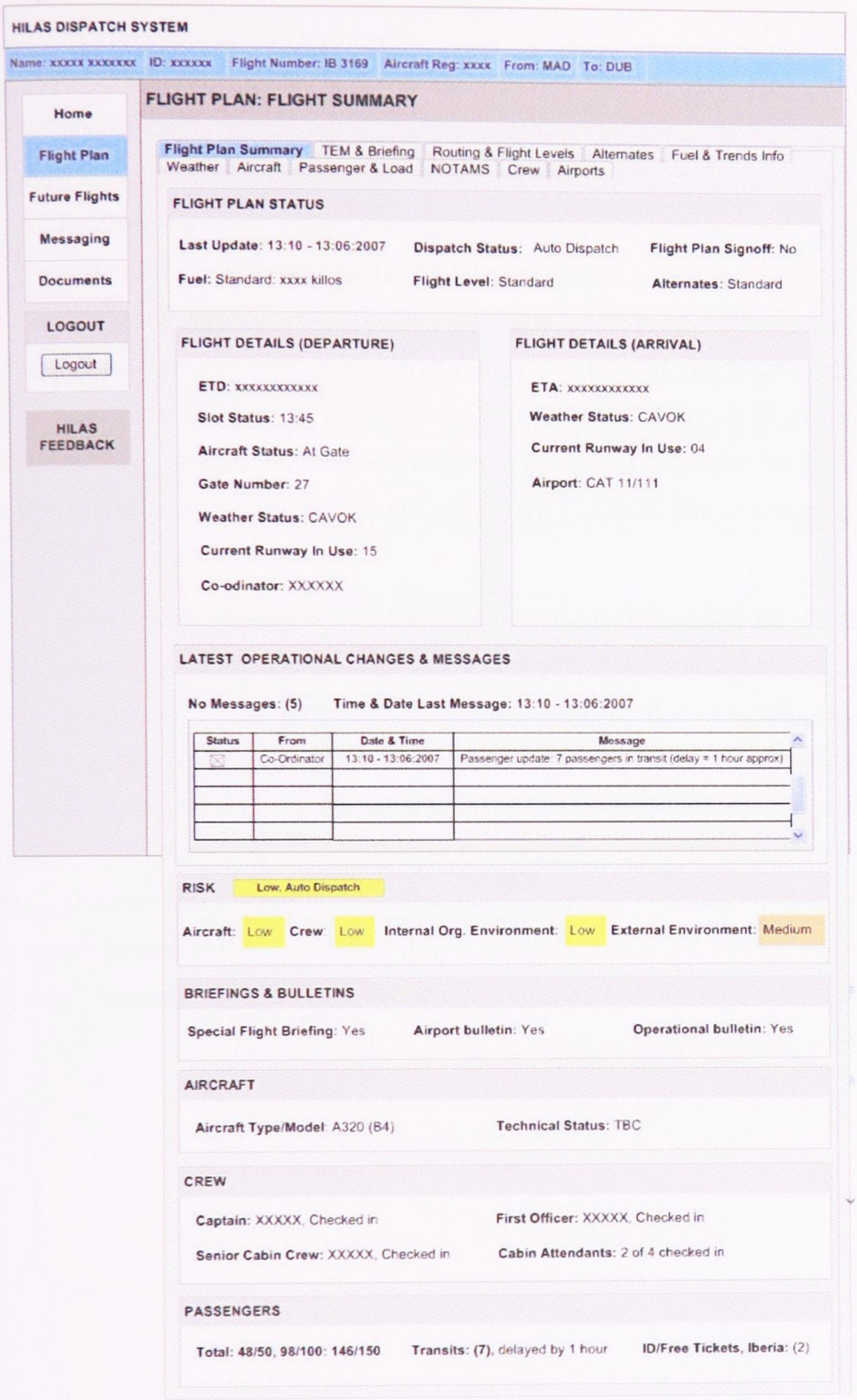

Figure 21: Dispatch Application: Flight Plan Summary Screen (Study 6)

TEM/Briefing Summary

It was suggested that the Flight Plan workflow would link to the reporting workflow. Crew might be required to report on certain flight threats identified by the system. This might link to broader safety management studies undertaken by the airline's Safety Department. It was agreed that an icon would be positioned beside certain threats indicating a requirement to complete a mandatory report describing how a specific threat was managed. At the briefing stage, the crew would enter information about how they proposed to manage the potential threat. The crew would not be required to start a report at this time. Any information entered by the user at this point would be pre-populated in crew reports. The requirement to complete a mandatory report related to the same flight threat would be flagged in the reports section. In this way, the report would capture information about how the threat was actually handled.

As illustrated in figures 22, 23, 24 and 25, several high involvement options were further specified. It was suggested that a link might appear beside each threat, which would launch a pop up window allowing Pilots to submit information about how they would manage a specific threat identified by the system. In the participant's view, other high involvement options should feature in a separate section termed 'high involvement'. This includes adding information about flight threats not recorded by the system, and sending briefing information to the senior Cabin Crew. In relation to the latter, it was agreed that the Captain would select what information would be sent to the senior Cabin Crew. It was also recommended that a rewards mechanism might be built into the use of high involvement options. However, the nature of this rewards mechanism was not specified.

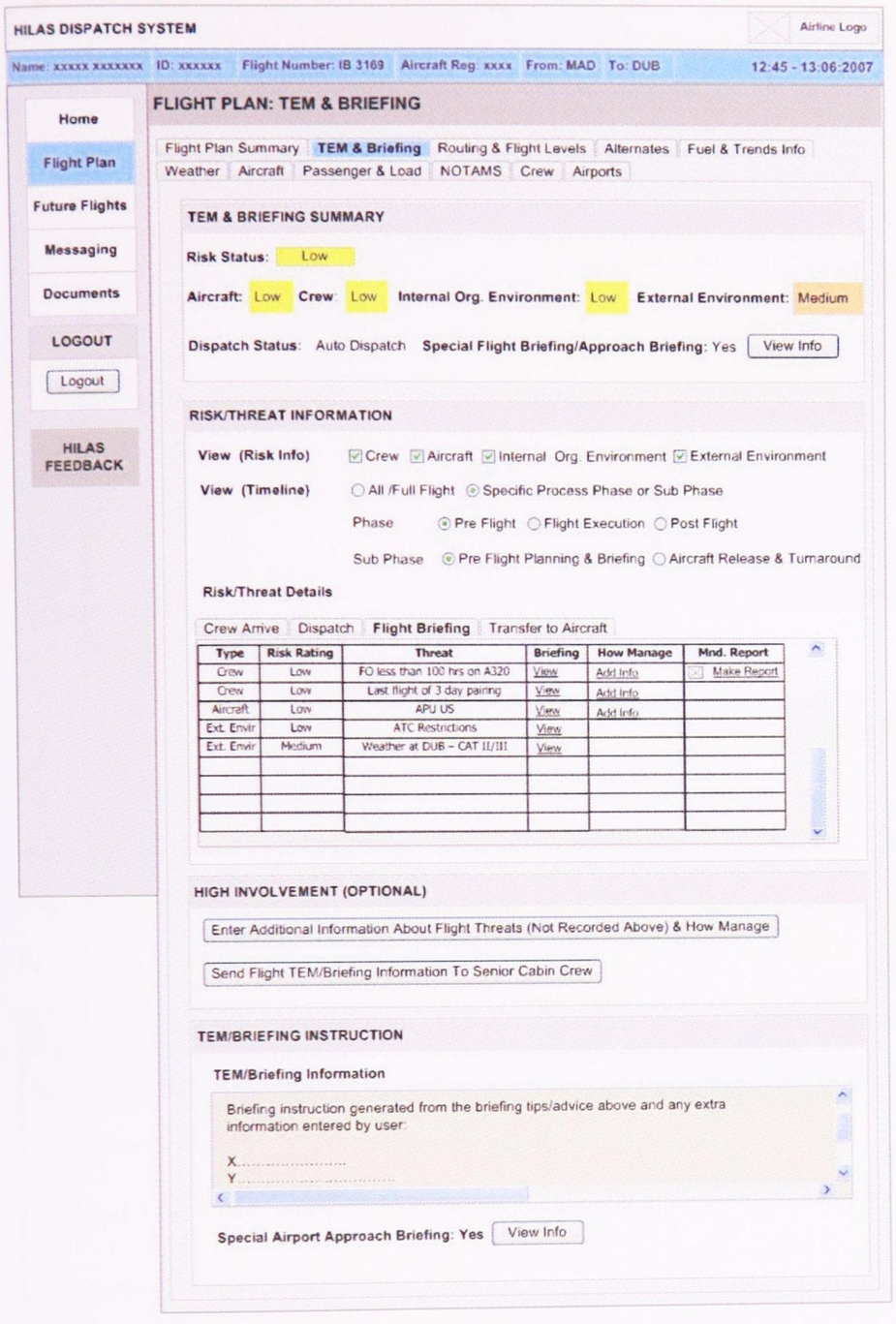

Figure 22: Dispatch Application: Flight Plan/TEM Screen (Study 6)

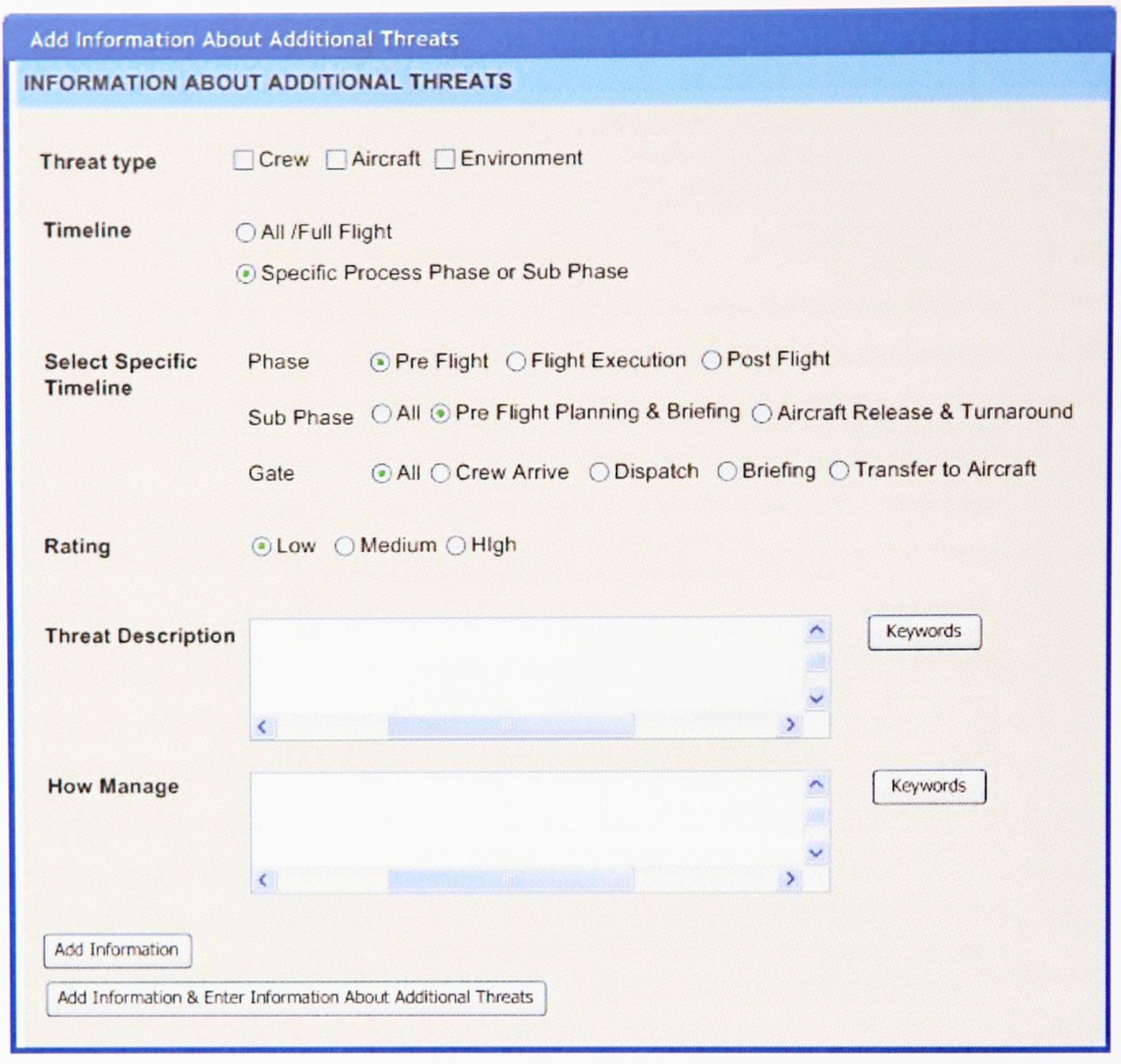

Figure 23: Dispatch Application, Add Information about Additional Threats (Study 6)

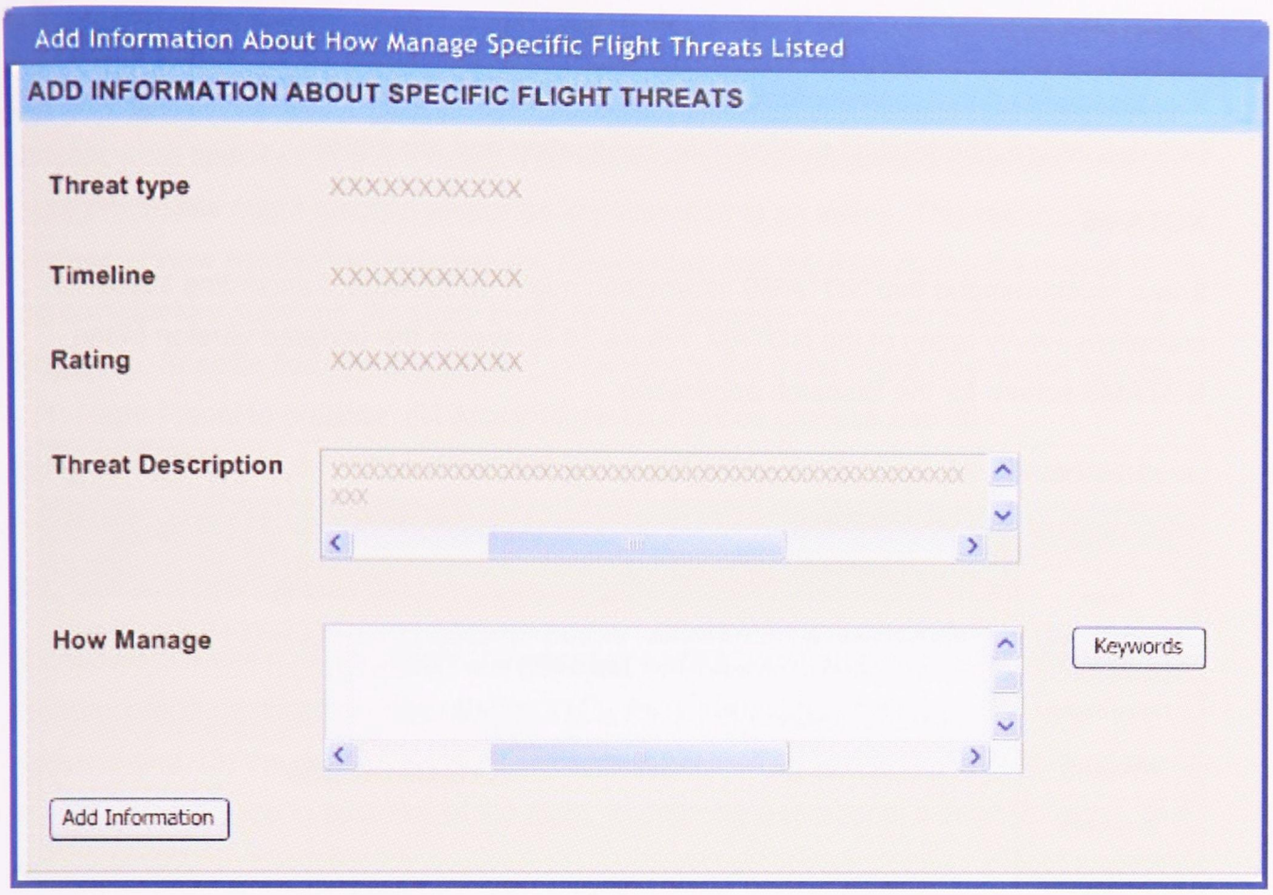

Figure 24: Dispatch Application: Add Information About Specific Flight Threat (Study 6)

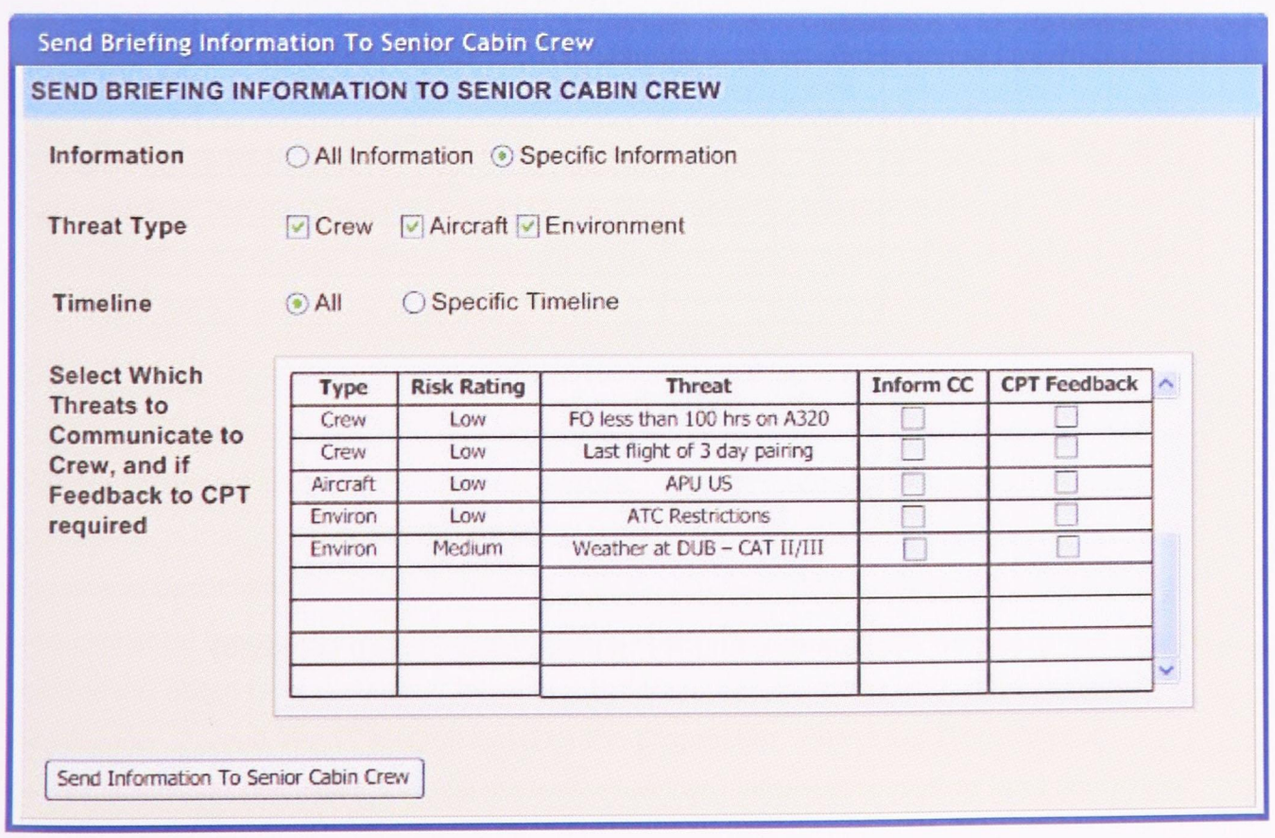

Figure 25: Dispatch Application, Send Information to Cabin Crew (Study 6)

Route Information

It was suggested that routes information should be chunked into three sections. This includes information relating to departure, destination and alternates.

NOTAMS

It was recommended that NOTAMS information might be structured according to the criticality/severity rating of the NOTAM. Figure 26 illustrates the updated version of the NOTAMS screen for the Dispatch application.

Figure 26: Dispatch Application, Flight Plan/NOTAMS Screen (Study 6)

Provisional Process Specifications

The new operational and organisational processes underpinning the Intelligent Flight Plan concept were specified in more detail. The following section presents a summary of how these processes might function and/or be implemented at an airline. This reflects the consensus view established between the Researcher and the Pilot during the course of the two participatory sessions. As such, these findings describe recommendations for future processes. Specific findings are outlined in relation to the three Flight Operations processes – (1) Flight Planning process, (2) Active Flight Operations process and (3) Safety/Quality/Improvement process. A summary of these new processes is provided in Appendix 12.

Flight Planning Process

In the new process concept, Flight Planning personnel obtain feedback about potential risks/threats to be considered in relation to (1) route planning, (2) aircraft pairing and rostering and, (3) the development of particular flight plan by Dispatch. Ideally, all relevant threats are mitigated in advance of the flight, to optimise operational safety. However, it is likely that all threats will not be resolved. As such, certain threats will be carried forward to the active operation, and flagged to Flight Crew, by means of the Intelligent Flight Plan.

Flight Planning personnel make use of both operational and safety data, as part of the Flight Planning process. In this concept, flight planning personnel obtain information regarding potential threats from safety personnel, following the analysis of operational and safety data. Different levels of feedback are provided. This includes information concerning overall fleet threats and threats pertaining to specific routes, airports and crew compositions. Also, key human factors issues to be considered at the flight planning stage are shared (i.e. crew composition and fatigue). Further, relevant operational information (i.e. typical flight times, delays and airport issues) is relayed.

The Dispatcher obtains similar information (i.e. general threats information and threats pertaining to specific routes, airports and crew compositions). The Dispatcher has access to information concerning fuel trends for a specific route, and typical flight times. Maintenance information is integrated in the Dispatchers system (i.e. information about aircraft technical status and associated threats). Further, the Dispatcher accesses information about relevant environmental threats (i.e. weather and ATC issues). The Dispatcher also accesses information about typical weather trends for the time of year, along with real-time weather information. Overall, the IT system used by the Dispatcher, allows the Dispatcher to generate a Flight Plan, which takes the collective flight information picture (and associated risk/threats information) into account.

In addition, the Duty Manager receives information about threats to be managed shortly before the flight (i.e. 12 hours to 1 hour). As such, the Duty Manager works in collaboration

with the Dispatch function, in relation to the management of flight risks, in the lead up to the flight.

Active Flight Operations Process

In relation to pre-flight task workflows, a new dispatch process is proposed. The nature of the dispatch process is determined by the risk rating of the flight. Underpinning the assignment of the risk level for a given flight, and the specification of the required dispatch process (i.e. auto-dispatch or person to person dispatch), is an assessment of the flight situation. This assessment is based on an analysis of all flight threats, in each of the proposed threat categories (i.e. crew, aircraft and environment). If the flight has a low risk rating, an auto dispatch is performed. In this instance, Flight Crew jointly review an electronic version of the Flight Plan in the crew room (i.e. Dispatch application), and/or in the cockpit (i.e. EFB application). Relevant flight plan decisions (i.e. choice of alternate and fuel) are made and the Flight Plan is signed off. Flight Crew can confer with Dispatch if required, but this is optional. Crew are not required to liaise with Dispatch and/or Flight Operations Control personnel, but can do so if they so wish. If the risk rating for the flight is either medium or above, a person to person dispatch is required. In such circumstances the crew must negotiate all relevant flight plan decisions (e.g. fuel uptake, choice of alternates and changes to flight levels/routing) with the Dispatch team and/or the Duty Manager. Depending on the crew location, this is done in person (i.e. crew room/home base), or communication is mediated via VHF Radio. In both instances, other operational roles are required to share relevant information with Flight Crew. In this way, the proposed Flight Plan aggregates relevant task outputs from other operational roles.

Throughout the flight, the crew receive updates regarding the unfolding situation (i.e. potential new threats). This includes information updates from both Flight Operations Control/Duty Manager, and from the Safety Department. The Flight Crew jointly review the threats picture with the Duty Manager and agree a course of action. Further, at any time throughout the flight, crew can enter in new information related to threats encountered.

The generation of flight specific TEM/threats information necessitates the completion of both mandatory and voluntary safety/human factors reports by Flight Crew. Critical here is the completion of voluntary reports describing near misses, threat and error management strategies, and improvement recommendations. In certain cases, a specific flight threat may be of interest to the airline's safety department in terms of ongoing evaluation/analysis that they may be undertaking. Accordingly, the crew are invited to make a mandatory report about how this threat is managed. At the pre-flight stage, the requirement to make this report is simply flagged to the crew. Crew can commence reporting activities. However, the final report must only be completed at flight close.

Moreover, reports would be completed by other operational roles (i.e. Cabin Crew, Ground Operations, Maintenance, Dispatcher and Co-ordinator).

Safety/Quality/Improvement Process

Overview

The introduction of the Intelligent Flight Plan concept is dependent on the parallel introduction of new performance/safety management processes, linking to the broader airline SMS process. Overall, this relates to improved data management processes linking to both reactive/retrospective risk management approaches, across different timeframes (i.e. short term/tactical and longer term/strategic) and proactive/prospective risk management approaches. In principle, these processes follow the following high level steps. Information is gathered about (1) events (i.e. safety critical events, near misses and delays) and (2) routine performance (i.e. normal operations/routine monitoring). This is achieved through the capture of reports information and aircraft technical data. This information is then integrated with other airline operational and safety data, so that an integrated picture of systems performance is obtained. This information is then analysed. This results in a picture of both existing threats/hazards and potential threats/hazards. Following the analysis, corrective actions are taken. Information concerning the nature of these threats and the associated corrective actions is communicated to all relevant personnel. Further, change actions are monitored to ensure that human factors/safety issues are appropriately resolved.

Several high level reactive and proactive risk analysis approaches were identified. Further, research also focussed on mapping the process underlying the generation of a flight specific risk rating. These are detailed below.

Reactive Approaches (High Level)

Several reactive risk management approaches implemented across different timelines were identified.

Firstly, a high level tactical approach (i.e. short term) was defined. If a safety critical event occurs (i.e. aircraft technical issue, bird strike and/or runway over-run) and/or a potential flight threat is reported (i.e. problem with landing equipment at an airport and/or ATC communication issue), this information is relayed to Flight Operations Control and Dispatch and other relevant functions involved in the problem (i.e. Maintenance and others). Ideally, the threat/problem is resolved in the short term. However, if the problem is not resolved and/or if the threat is relevant to the next crew/flight, the crew obtain relevant threats information in the Intelligent Flight Plan. Depending on the timeline, this takes the form of a threat listing in the TEM section, or an operational update. Importantly, all information/TEM information is reviewed by Safety personnel and/or the Duty Manager, before being communicated to Flight Crew.

More strategic approaches were also identified. Individual events (i.e. near miss, safety critical events and delays) are analysed in more detail by a range of airline functions (i.e. Safety, Risk, Training and Procedures Design). This analysis focuses on identifying the reasons for the event (i.e. contributory factors and root causes) and appropriate corrective actions. Critically, all relevant parties are informed about the output of this analysis. This includes Flight Planning, Dispatch, Procedures Design, CRM Training, Flight Crew and Cabin Crew.

Trending analysis in relation to all reported events is also undertaken. The analysis focuses on identifying the key threats faced by crew, contributory factors and root causes. From this, a picture of operational threats is developed. In principle, this picture includes the following dimensions: categorisation of threats (i.e. crew, aircraft and environment), location in the process, functions involved, frequency occurring, assessment of severity of their outcome, risk rating, and relationship to other threats/hazards. The emerging risk picture is filtered in relation to several key parameters. This includes: fleet, route, the departure/origin airport, the destination airport, time of day, aircraft and crew composition. Again, feedback from these analyses is communicated to the right personnel.

Further, more specific analyses are undertaken in relation to threats pertaining to a specific flight/route, airport, and/or crew composition. Alternatively, an analysis of crew reports in relation to specific human factors problems/issues encountered (i.e. poor communication between Flight Crew, lack of teamwork between Flight Crew and Cabin Crew and/or poor information sharing between Dispatch and Flight Crew) is undertaken. Again, feedback from these analyses is communicated to the right personnel.

Proactive Approaches (High Level)

A high level proactive approach was also identified. As part of this, both reports information and aircraft technical information is routinely gathered. Further, additional system performance information is gathered from other sources. This includes existing reports, new reports (i.e. dynamic reports picture), reports concerning prior retrospective risk evaluations, other human factors evaluations, information from weather systems, information from maintenance systems, and information from human resources systems (i.e. crew information). Overall, this information is integrated and analysed to obtain an assessment of the safety/risk status of the operation, and to predict potential operational risks. Potential operational threats might be filtered in relation to fleet, route, aircraft, origin and destination airports, crew and crew composition. Following this, corrective actions are taken. Further, change actions are monitored. As before, feedback is relayed to all relevant parties.

Generation of Specific Flight Risk Rating & TEM Information

It was noted that the process underpinning this risk assignment for the total flight (i.e. consideration of all threats pertaining to the flight) is potentially quite complex. As reported

by the Pilot: *"the proposed calculation needs to take into account the dynamic of how different threats relate to each other and the weighting of different threat categories"*. The same issues apply for the generation of a risk rating for the cumulative threats in a specific threats category (i.e. aircraft, crew and environment). Again, in the case of related risks that might arise individually and/or collectively, an appropriate additive risk assessment is made. The risk rating for individual threats/hazards is potentially more straightforward. This is calculated by assessing (1) the probability of their occurring and (2) the severity of their outcome.

Data Supporting the Generation of Specific Flight Risk Rating & TEM Information

The assessment/rating for a particular flight is based on an evaluation of three sets of analysis data, each pertaining to the flight situation. This includes data related to (1) the existing flight situation/context (i.e. dynamic information to include latest real time reports), (2) what is known from SMS reports/analysis (i.e. both proactive and retrospective risk analysis), and (3) what is known from operational analysis (i.e. Flight Operations trending reports). An example of the different sets of data is provided in Appendix 13.

The first level of analysis pertains to the existing situation or context. The situation is assessed in relation to three categories: crew, aircraft and environment. Each category includes certain sub-categories. Overall, a risk assessment is made for each sub-category (i.e. low, medium or high). Further, a cumulative assessment for each category (i.e. assessment in relation to crew, aircraft and environment) and for the total flight (i.e. taking into account all categories) is made. In relation to crew, an analysis of crew threats, both on an individual and team level (i.e. crew composition) is made. The risk status of the aircraft relates to its technical status (i.e. MEL status and checks schedule). Environment concerns everything related to the context on the day (i.e. weather, routing and ATC). Overall, this involves gathering, integrating and analysing information from a range of resources, including human resource information (i.e. crew profile), dispatch information (i.e. weather, routing and fuel), and maintenance information (i.e. aircraft check schedules and aircraft technical logbook).

In relation to what is known from SMS/reports, this links to retrospective risk management processes (i.e. analysis of reports), and the analysis of flight technical information.

Lastly, in relation to operational analysis - several trending reports are compiled. This includes: average duty schedules, duty schedules and requests for extensions, frequency of crew changes (i.e. sick crew, roster issues and duty issues), frequency of aircraft changes, frequency of aircraft technical issues identified at turnaround, fuel trends and flight delays. Route data is trended (i.e. typical routes, typical ATC requests, and environmental issues to be considered such as terrain and weather patterns). Further, specific airport data is trended (i.e. typical services required, problems at specific airports, typical ATC holding patterns,

frequency of aborted takeoffs, particular geographical features impacting on takeoff/landing procedures, frequency of go-around's required, and typical quality of takeoff/landing [within SOP/outside SOP] and weather trends).

Briefing Information

Specific briefing guidance is gathered from crew reports, training information, safety case studies and best practice human factors information. Overall this information is continuously reviewed, to ensure that it is both current and appropriate.

Management of Crew Threats

Preliminary concepts related to the management of information pertaining to crew threats were explored. This involved the specification of a number of related concepts and processes. This includes (1) the dynamic crew profile and the identification of crew threats pertaining to a specific individual, (2) the crew composition risk matrix and the associated identification of threats related to crew pairings, (3) the intelligent matching of crew members as part of the flight planning process, and (4) the joint review of crew threats as part of the pre-flight planning and briefing process.

In terms of the dynamic crew profile, it was agreed that the system gathers key information about individual Pilots. This includes the following information: name, age, training background, training received, training due, license expiry, fleet experience, route experience, airport experience, problems encountered, reports filed, most recent flight, distance to work, mode of transport to work, holidays, sick leave and if recently bereaved. This information is updated in real time, so that a real time picture of the status of individual crew members is obtained.

The risk status of a specific crew member is established based on an analysis of the crew profile. For example, if a crew member is fatigued, or recently bereaved, or has minimal experience in a particular aircraft type, they might present a risk to the operation. Further, if this is the first time the crew member is flying the particular route, this might present a low level threat.

Further, a number of high level principles pertaining to safe and unsafe crew compositions were defined. This includes ideas related to the overall fleet experience of the crew, the fatigue levels of crew members, and the crew member's training background (i.e. civilian or military). For example, if the Captain and the First Officer are both fatigued, or have recently moved to the fleet, this might be considered a high risk pairing. Overall the system stores information about the status of crew members. A set of rules/logic is built into the system related to safe and unsafe crew states. Moreover, logic is defined in relation to safe and unsafe crew compositions. During the aircraft pairing and rostering stage, the system flags any potential crew composition threats. Ideally, a good crew composition is achieved.

At the pre flight stage, the Intelligent Flight Plan presents the crew with an overall risk rating in relation to crew threats, along with detailed information about specific crew threats (i.e. crew fatigue, new First Officer with limited fleet experience, crew member recently returned from sick leave or bereavement leave).

Implementation Workshop

Overall Concept

Workshop participants responded favourably to the proposed Intelligent Flight Plan concept. Specifically, participants welcomed proposals to embed the Flight Plan in the broader flight operations process. That is: (1) supporting information sharing across the different agents involved in the flight operation, and (2) providing feedback to Flight Crew regarding the outcome of ongoing airline safety/risk analyses (i.e. integrating SMS processes and tools and Flight Crew tools).

All participants understood the overall link between the different tools and processes. Specifically, participants welcomed the idea that Flight Crew reports relating to the identification and management of both operational and environmental threats, along with crew errors, would be analyzed by airline safety and risk personnel, for the purposes of (1) ongoing safety management, (2) providing feedback to Flight Crew to support pre-flight, flight planning and briefing activities, and (3) improving Flight Planning and Dispatch processes.

Participants emphasized the importance of the Flight Plan in terms of supporting Flight Crew briefing and planning tasks. It was agreed that the provision of new information in the Flight Plan would provide additional task support for Flight Crew, specifically in terms of joint flight planning and situation assessment. In so doing, the proposed Intelligent Flight Plan would bolster flight safety.

Participants highlighted the criticality of Flight Crew obtaining the latest flight information and operational updates at the right time and in the right format. In line with prior research, Flight Crew participants observed that currently there is a lack of information integration across the different airline functions, in relation to the communication of flight plan updates (i.e. slot changes) and/or relevant operational updates (i.e. aircraft changes, maintenance status and load changes). This was affirmed by the Dispatch representatives. In line with earlier research, Flight Crew participants stated that they pull information from the system, information is not pushed to them. In this respect, both Flight Crew and Dispatch participants observed that the proposal to integrate information updates from different operational roles (i.e. Maintenance, Co-ordinator and Operations Control/Duty Manager) in the Flight Plan is a welcome step forward. Although the flight plan provides certain operational information, it was noted that this is not updated in real time. Also, the specific currency of flight plan

information is not always transparent. For example, participants reported that the existing Flight Plan does not indicate the rationale for the recommended fuel figure (i.e. whether the latest weather or ATC information has been incorporated in the recommended fuel figure provided by Dispatch). For this reason, it was agreed that all information should include a time reference.

All participants welcomed the provision of flight specific threats information. Participants understood the overall risk rating for the flight (i.e. low, medium and high). It was suggested that the overall risk logic behind this classification would require agreement from a number of relevant departments including Flight Operations, Dispatch, and Safety. Several participants noted that the practical implementation of this concept (i.e. specific process for generating a flight specific risk rating) would need to be established. It was observed that the underlying risk assignment might follow an expert judgement in relation to overall flight threats, as opposed to a complex risk calculation generated by an IT system, factoring overall threat weightings and relationships.

All participants welcomed proposals to embed both CRM and TEM concepts in the Intelligent Flight Plan. Both Flight Crew and Safety participants acknowledged that although these concepts and associated techniques are taught in the classroom, it is not guaranteed that Flight Crew will deploy them in the active operation. In keeping with the findings of earlier research, Flight Crew participants suggested that the practice of CRM and TEM techniques supports teamwork and specifically joint situation awareness and assessment. Participants stated that the provision of information concerning potential flight threats and associated best practice threat management tips, would encourage crews to review potential flight threats and related management strategies together. As stated by a First Officer, "CRM behaviours are put centre-stage". Further, as pointed out by a Captain, *"the design of the intelligent flight plan is such that it encourages teamwork and specifically joint situation assessment"*. Both Dispatch and Flight Crew participants observed that TEM information might also be available to the Dispatcher, the Co-ordinator and the Duty Manager on the day, to enhance co-ordination with Flight Crew and associated decision support functions.

User Interface Design & Workflow

Flight Summary Screen

As illustrated in Figure 27, it was suggested that the summary of operational updates should include the date/time of the message and an icon to denote the read status of the message.

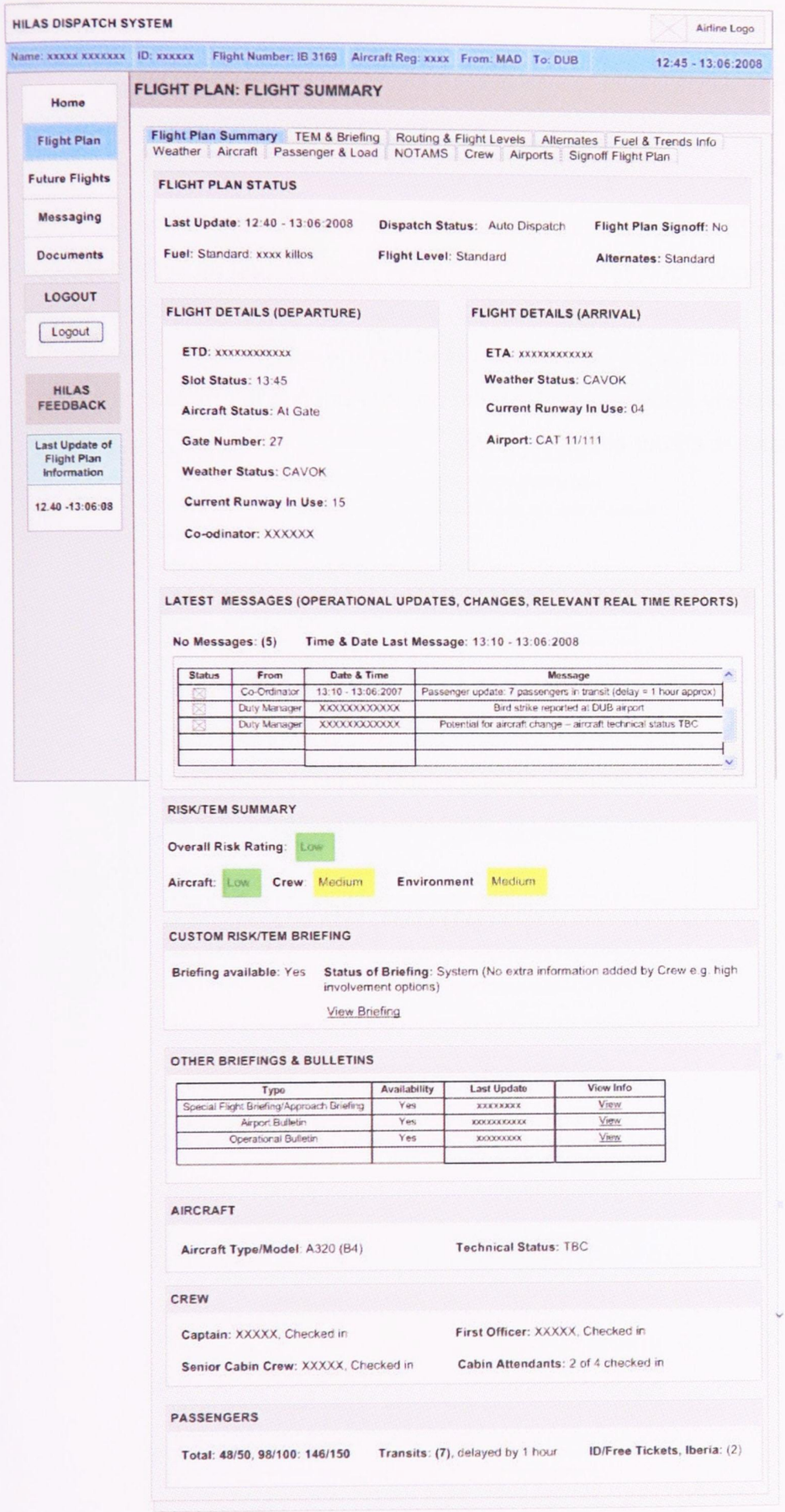

Figure 27: Dispatch Application, Flight Plan Summary Screen (Study 6)

TEM/Briefing Summary

Consistent with earlier findings, participants agreed that TEM information should be organised in relation to the overall process timeline and associated flight gates (i.e. process phase, process sub-phase, process gate/critical point) as opposed to flight phases.

As depicted in Figure 28, participants suggested that the colour coding for the flight risk status should change. Participants remarked that low risk flights should be highlighted green and not yellow. Further, participants suggested that medium risk might be coloured amber and high risks red. Lastly, workshop participants noted that the specific CRM briefing information might be visually distinguished from the broader briefing information such as links to operational bulletins and/or airport bulletins.

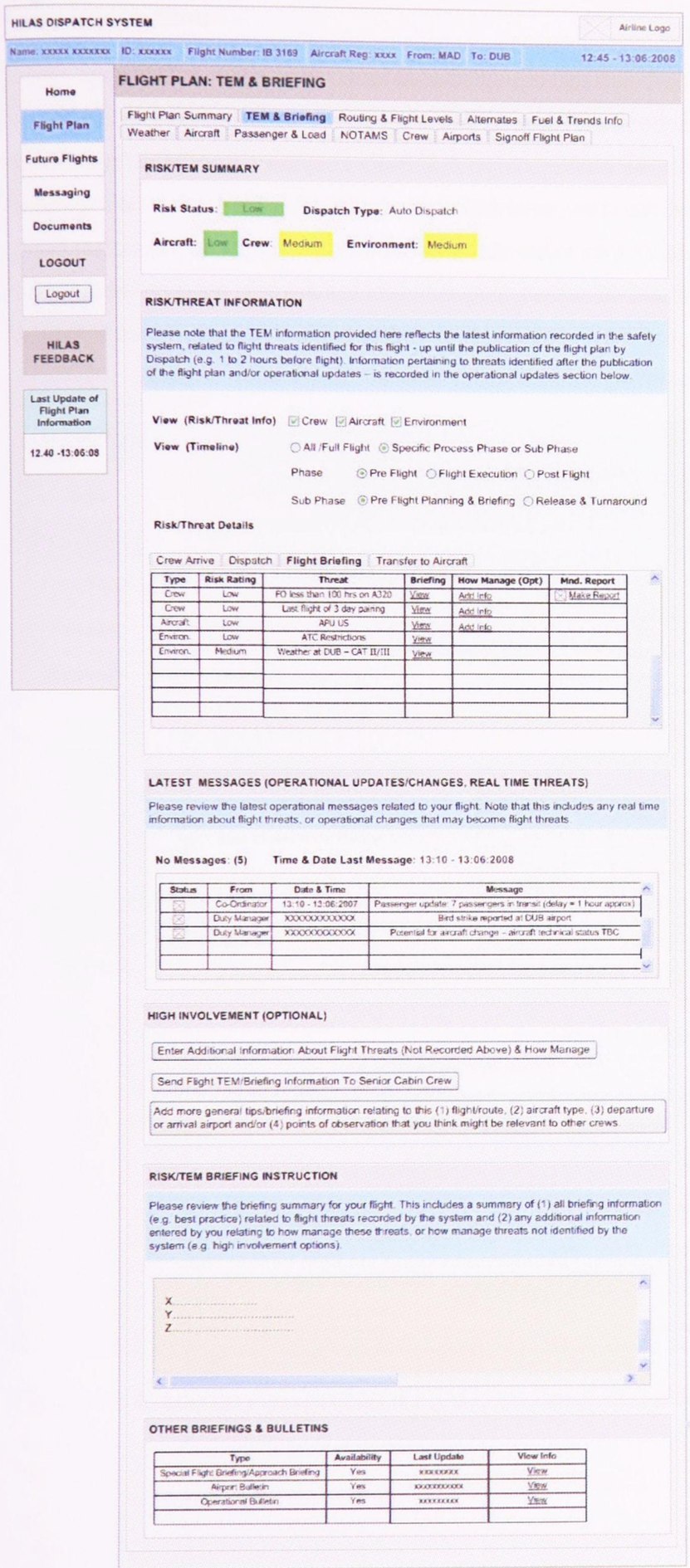

Figure 28: Dispatch Application, Flight Plan/TEM Screen (Study 6)

Fuel Information

As represented in Figure 29, participants requested that fuel composition information specifically state (1) what additional contingency fuel was added by Dispatch and (2) the reason for this. Flight Crew representatives noted that there may be a number of reasons to add contingency fuel. Critically, the crew need to know whether the Dispatcher has taken into account all of the reasons that they have identified at the pre-flight briefing stage. For example, the Dispatcher may have added contingency fuel to take into account adverse weather conditions. However, the crew may feel that additional fuel is also required given their knowledge of the holding arrangements/patterns at the destination airport.

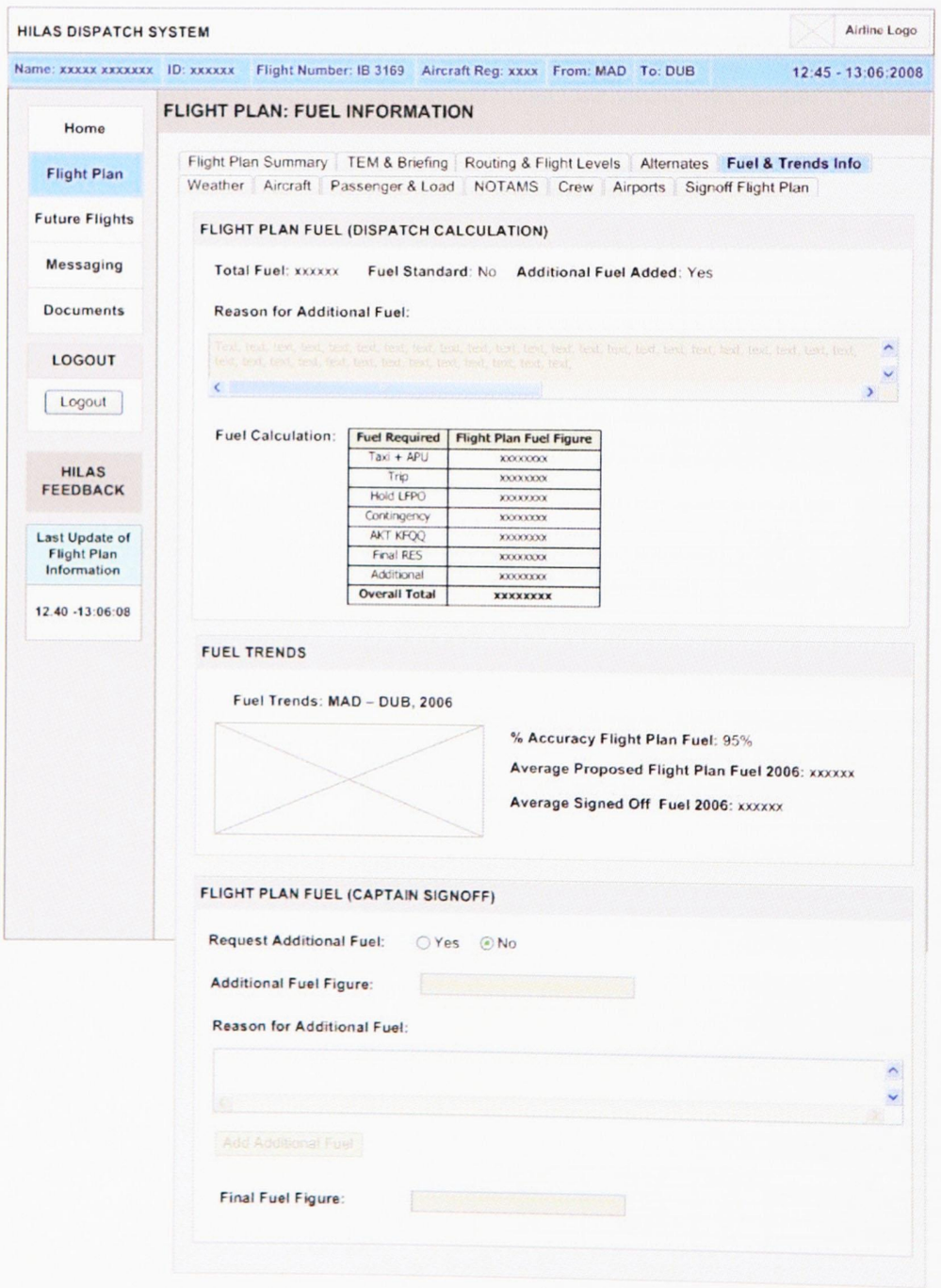

Figure 29: Dispatch Application, Flight Plan Fuel Screen (Study 6)

Crew Information

It was agreed that limited personal details should be provided. As illustrated in Figure 30, this includes the crew member name, rank and photo. Further, it was observed that certain minimal information should be included related to the crew member's background to facilitate briefing. This includes fleet experience, experience of route and date of last flight for the given route. All participants noted the importance of importance of providing photo information for crew members, to facilitate the easy identification of fellow crew members in the crew room.

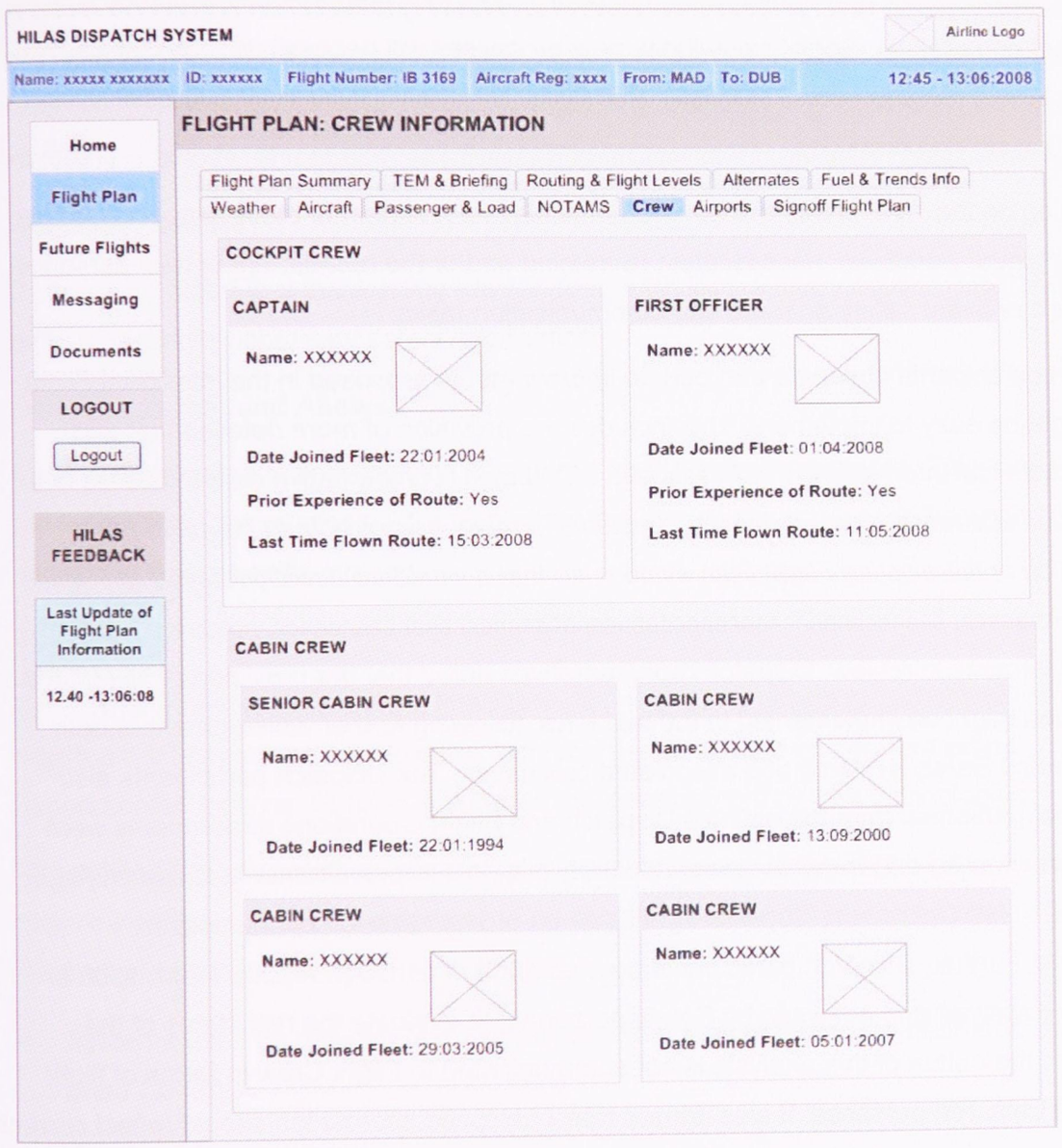

Figure 30: Dispatch Application, Flight Plan Crew Screen (Study 6)

Implementation Challenges

Several challenges linked to the implementation of this process have been identified.

Process design/Information Sharing

Workshop participants stated that to a large degree the implementation of the Intelligent Flight Plan concept would necessitate the specification and implementation of new operational and organisational processes. This includes process re-design in relation to core SMS and flight planning processes, and other processes (i.e. Maintenance and Ground Handling). Consistent with earlier research, participants indicated that this would be a significant undertaking. Specifically, these new processes will necessitate information sharing across departments. Potentially, there may be a level of resistance to new information sharing practices.

Depending on the level of technology support achievable, certain of these processes might require manual workflows, necessitating re training and/or the recruitment of new personnel to perform relevant safety analysis and communication tasks.

Dispatch participants observed that certain improvements proposed in the intelligent Flight Plan might be easy to implement. This includes the provision of more detailed fuel and aircraft technical information. In this respect, a Dispatch representative stated that *"as this information is already displayed in their systems, it might be possible to populate this information in the existing Flight Plan system, so that it would be directly relayed to Flight Crew"*. However, the airline IT representatives observed that this would require a detailed systems integration review. Dispatch representatives noted that the provision of TEM/CRM information might be implemented in the mid term, following further development of both Dispatch and Safety systems and associated processes. The Dispatch participants also stated that personnel from the airline's Dispatch and Flight Operations departments were currently reviewing existing processes to identify possible improvements to Dispatch/Flight Crew and Flight Operations Control/Flight Crew co-ordination and communication processes. Further, Dispatch participants pointed out that although reports information is currently reviewed and analysed by Safety personnel to evaluate the risk status of the operation, the output of this analysis is not communicated to Flight Crew in terms of flight specific TEM/CRM guidance. It was agreed that TEM/CRM information should reflect current best practice in relation to the management of threats. This would require gathering, integrating and analysing best practice information across different organisational functions (i.e. Training, Procedures and Safety). Further, additional information might be elicited from crew. This might include the analysis of reports data along with feedback obtained during crew CRM training sessions. Dispatch personnel also highlighted certain improvements to the existing Flight Plan, to be implemented at the airline in the coming months. This includes

the introduction of read only flight plan information which Flight Crew will review and print using the existing crew room computers.

A safety representative also responded favourably to the Intelligent Flight Plan concept, albeit cautioning that *"This would necessitate considerable improvements to existing data management processes"*. Specifically, the Safety Representative stated: "*The provision of custom flight threats/risk information would create extra workload for the Safety department and might not be possible given existing resources*". It was also suggested that depending on the level of technology support achievable, certain of these processes might require manual workflows, necessitating the recruitment of new personnel to perform relevant safety analysis and communication tasks. The Safety representative noted ongoing activities in relation to the development of the airline's SMS - acknowledging weaknesses in existing reporting methods, and specifically Safety/Flight Crew communication mechanisms.

Reporting culture

Participants noted that the existing low reporting rate for voluntary reports might make it difficult to gather necessary safety information.

Data Integration and Analysis

Much data integration and analysis is required for the above processes. This includes (1) modelling normal operations, (2) establishing the overall risk picture for the operation and (3) assessing flight specific threats.

Technology

Lastly, the implementation of the intelligent planning concept and processes will require significant integration across existing technical systems used by different airline departments/functions. Further, it requires the development of new technologies.

The airline IT representatives stated that the advancement of the Flight Plan concept would require significant systems integration. Specifically, participants referred to potential integration between the following systems:

- Systems used by relevant operational roles (i.e. Maintenance, Co-ordinator, Fueller and Load Control)
- Flight planning system
- Dispatch system
- Flight Operations Control system
- SMS system.

Further, this would require the development of additional technology for use by other roles. For example, this necessitates:

- Enhancements to existing tools used by Dispatch and Flight Operations Control, to support joint decision making and information sharing with Flight Crew
- Enhancements to existing tools used by other operational personnel (i.e. Fueller, Maintenance, the Co-ordinator and Cabin Crew), to support information sharing functions with Flight Crew
- The introduction of new SMS tools supporting data integration, analysis and communication
- The introduction of new reporting tools for use by other operational and management roles.

Practical Implementation

As noted by participants, the process for generating a risk rating for a specific flight must be feasible from an implementation perspective. Potentially, it may not be possible to assess the risk status of the flight, as initially proposed. Participants observed that it may not be possible to make an assessment in each of the sub categories defined for the first level of analysis (i.e. current situation). Equally, the proposed level of analysis for SMS information and operational trending information may not be achievable.

All participants stated that the advancement of the proposed system would necessitate training for a number of airline functions (i.e. Flight Crew, Dispatch, Flight Operations Control, Safety, and Training) both from a process design and technology usage perspective. Flight Crew participants also emphasized that they would require training in the use of each of the three proposed Flight Crew applications (i.e. Personal, Dispatch and EFB).

4. DISCUSSION

Intelligent Flight Plan Concept

Difficulties accessing information and/or late information have an adverse impact on crew situation assessment and decision making. Decision outcomes and flight safety can be improved by providing Flight Crew with all relevant task information. This includes relevant process information (i.e. task inputs and information updates from other operational roles), and information supporting pilot situation/risk assessment and the identification of appropriate threat and error management strategies (i.e. CRM/TEM support).

The development of an electronic version of the Flight Plan affords the opportunity to rethink the Flight Plan concept in terms of enhancing information flow across the wider socio-technical system. Overall, the introduction of this new Intelligent Flight Plan concept results

in a new way of performing the pre-flight, planning and briefing task and new Flight Operations processes.

It is argued that the new Flight Plan concept will enhance safety through improving system information flow and associated crew situation awareness and assessment. Moreover, in addition to enhancing Flight Crew practice of the pre-flight, flight planning and briefing task, this might also have the added benefit of high involvement and reducing procedural drift. Nonetheless, in the low cost business environment, enhancing human factors and safety may not be enough. In this respect, the transition from a paper to an electronic Flight Plan, which is accessible both inside the cockpit (i.e. EFB application) and remotely (i.e. dispatch and personal applications), may also result in operational efficiencies and cost savings.

Process Redesign & Implementation Challenges

This research has resulted in the preliminary specification of several operational and organisational processes necessary to the implementation of the proposed Intelligent Flight Plan concept. Currently, these processes either do not exist and/or exist only informally. As such, several process redesign changes are required. In terms of operational processes, this concerns changes to existing flight planning processes spanning several functions (i.e. Flight Planning, Dispatch and Flight Operations Control). It is likely that the implementation of such changes will be both gradual and slow. However, the airline is already making steps toward such changes such as the provision of electronic access to the Flight Plan. It is anticipated that these changes will pave the way for the introduction of the Intelligent Flight Plan at the airline. In terms of organisational processes, this involves changes to existing performance/safety management processes pertaining to the management and use of safety information. Overall, this involves the implementation of both proactive and reactive safety/risk management approaches, across different timeframes following ICAO recommendations (2006, 2009). In principle, this supports the distributed information processing practices associated with high reliability organisations as proposed by Weick and Roberts, (1993) and Weick, Sutcliffe and Obstfeld (1999). Moreover, it is anticipated that these new processes will go some way towards mitigating 'information disasters' as defined by Turner (1978) and Turner and Pidgeon (1997).

The successful implementation of the Intelligent Flight Plan rests on addressing all relevant implementation barriers, as identified in this research. As shown, implicit in the Intelligent Flight Plan concept is the requirement for enhanced information sharing across different airline departments/functions. Initial research suggests that there may be resistance to this. Thus, in advance of implementing the Intelligent Flight Plan concept, more fundamental issues related to the information sharing culture at the airline may need to be resolved. Further, certain Intelligent Flight Plan features may not be easily implemented. The work

effort necessary to populate risk information for individual flights is considerable. Although useful from a Pilot perspective, the organisational effort necessary to implement this for all flight plans may be too great. This requires further analysis. The implementation of the Intelligent Flight Plan concept requires that appropriate operational/safety data can be gathered about the operation, supporting both proactive and reactive risk assessments. Critical to this, is the generation of routine reports by frontline personnel and especially, by Pilots. Low reporting rates may also prove a challenge. Lastly, many technology integration issues were identified and will require more detailed consideration.

Risk Assessment for Each Flight

Central to the Intelligent Flight Plan concept is the assignment of a risk rating for the proposed flight (i.e. low, medium or high). As reported, what is in question for each flight, is what set of threats/hazards the crew are potentially facing, and what the specific impact of this grouping of threats is (i.e. relationship between threats). Critically, the assessment of the risk status of the proposed flight must take into account the cumulative threats picture. In the case of related risks that might arise individually and/or collectively, an appropriate additive risk assessment must be made. This is not a straightforward task.

Ideally, the assignment of risk for particular flight, and population of threats information would be an automatic process. That is, a specific risk analysis system might be designed to gather and evaluate all threats information and generate risk assessments for particular flights. However, this would necessitate considerable effort in relation to the specification of the system risk logic and specific systems development. Further, some manual/expert input might be required. In the short term, existing systems might be improved in relation to identifying relevant threats/hazards information for a particular flight. The safety/risk analyst might query a central risk system to identify relevant threats information related to the specific flight (i.e. fleet, aircraft type, aircraft registration, crew/crew profile, crew composition, the origin and destination airport, routing, time of day and weather). This information would be derived from relevant retrospective and prospective risk management analyses. The analyst would decide what specific threats pertain to the flight. Further the analyst would assign a risk rating based on an expert judgement. As part of this, the analyst might refer to a checklist of rules related to the assessment of risks. This would need to be specified.

In the new concept, risk/threats information for a particular flight is relayed to Flight Crew in terms of the Intelligent Flight Plan. Potentially, this process might be implemented differently depending on specific airline requirements. It is conceivable that certain airlines may want to manage the communication of flight specific risk/TEM information differently. Perhaps the provision of detailed information about environmental threats in the Flight Plan is not controversial. However, the provision of information about aircraft and/or crew threats might

be conceived differently. Certain airlines might perceive this information as sensitive. Some airlines may not be comfortable communicating this level of safety/operational analysis to Flight Crew. This information is nonetheless important. In this respect, an alternative solution might be to communicate this information to other functions that have leverage over the operation (i.e. Dispatch, Flight Planning and/or the Duty Manager). This requires further consideration.

Crew Management: Active Human Factors Management

Underpinning the proposed Intelligent Flight Plan concept is a human factors philosophy that Pilots are the *"real engine of the operation"*. It is argued that the Flight Crew task involves more that what is currently conceived. Specifically, the Flight Crew task goes beyond flying the aircraft and interacting with different human agents and tools in accordance with SOPs. Rather, the Flight Crew task involves managing different levels of complexity associated with the physical flight environment, the team environment and the broader operational and organisational system. Although environmental and aircraft threats are important, what is most important is how these are managed by Flight Crew. As shown, in managing different levels of complexity, the Flight Crew co-ordinate task and information inputs across different agents involved in the Active Flight Operations process and other processes linked to this process.

Just as the physical engine of the aircraft has different characteristics and states - so does the Pilot. The Pilot can be defined in relation to competencies (i.e. social, cognitive and technical skills), experience (i.e. recent experience, knowledge of routes/airports etc), ratings (i.e. flight checks, simulator checks and ground school checks), level of fatigue, safety events, English proficiency, attendance at courses and so forth.

Overall, the proposed crew management concepts and processes advanced in this research should support the successful management of the Pilot in relation to (1) operational functions, such as crew rostering and flight execution and (2) organisational functions such as crew training and performance evaluation/monitoring. Collectively, the implementation of these concepts and processes spans several different department functions; namely, Human resources, Training, Safety, Flight Planning and Dispatch. This represents an attempt to marry core human factors concepts related to team formation, information sharing and briefing, with the intelligent design of IT systems supporting broader airline safety and risk management processes. Evidently, these concepts are preliminary and require further development.

Intelligent Planning

Underpinning the Intelligent Flight Plan concept is the notion of intelligent planning. Intelligent planning integrates several flight operations processes and functions, across the flight operations process timeline. This includes:

- Crew management (i.e. training, performance evaluation and crew pairing)
- Risk analysis undertaken by Safety personnel
- Safety feedback to Flight Planning
- Management of threats by Flight Planning and intelligent crew pairings
- Management of threats by Dispatch
- Depending on risk status of the proposed flight, auto dispatch or person to person interaction between Dispatcher and Flight Crew
- Flight Crew TEM at pre-flight, flight planning and briefing stage
- Ongoing communication/TEM between Flight Crew and Duty Manager/Flight Operations Control
- Flight Crew reports at end of the flight, or at any time.

Further, it involves information sharing/integration with other relevant processes/functions such as Maintenance and Ground Operations. The intelligent planning concept is a multi-layered concept and can be conceived on several related levels. That is, in relation to: (1) information flow (2) planning, (3) safety/risk management and (4) task support. Intelligent planning involves different airline functions making use of and sharing (1) operational information and (2) intelligence/analysis information at different points in the Flight Operations process timeline, to meet both operational and safety goals. Accordingly, different operational functions share relevant operational information and updates with each to support common operational goals. This involves information sharing/integration across Flight Operations, Maintenance and Ground Operations functions. Further, all functions share relevant intelligence/analysis information with each other. Intelligence/analysis comprises both (1) operational analysis (i.e. delays and fuel consumption) and (2) safety/risk/performance analysis (i.e. outputs of reactive and prospective risk management activities). From a planning perspective, the objective is to exploit the outputs of both (1) operational and (2) safety/risk analysis in the two operational processes - namely, the planning process and the active operation. In line with the ICAO SMS specification (2006, 2009), the intelligent planning concept utilizes both proactive and retrospective risk management logics. Lastly, there is a task support dimension to the intelligent planning concept. Intelligent planning involves integrating information flow across team agents to

support collaborative work. This follows from core human factors training concepts such as CRM and TEM. It is anticipated that this will support team formation, team briefing, shared situation awareness and joint situation assessment.

5. CONCLUSIONS

Existing tools fail to provide adequate task support for the pre-flight flight planning and briefing task. Further, the existing 'state of the art' fails to address Flight Crew task problems at the pre-flight stage.

Flight Crew information flow problems along with the specific task problems pertaining to the execution of the pre-flight, flight planning and briefing task can be usefully addressed and potentially ameliorated via the specification and implementation of process design improvements, linking to the advancement of a risk based Intelligent Flight Plan. Overall, it is proposed to make use of relevant operational and safety information to enhance (1) flight planning, (2) Dispatch and (3) pre-flight, Flight Crew planning and briefing. It is anticipated that such improvements will improve flight safety.

The new information sharing processes underpinning the Intelligent Flight Plan will require process re-design changes across the three Flight Operations processes. It was anticipated that these processes and the associated information flow logic would be further specified during the course of the implementation workshop. However, given time constraints, this was not achieved. Critically, the risk logic underlying the proposed Intelligent Flight Plan concept and associated SMS process requires further definition.

Once developed, it would be important to test these concepts. Ideally, this might involve user testing, along with evaluation in the proposed operational setting. In both cases, it would be useful to evaluate a number of performance measures such as time to task and error rates. In addition, user satisfaction ratings might be elicited.

Discussion

1. CHAPTER INTRODUCTION

This chapter discusses the collective findings of the six thesis studies. The discussion is divided into five sections. First, the emerging model of Flight Crew task performance is presented and discussed. This forms a large section of this chapter. Primarily, this analysis aims to both extrapolate and ground the theoretical frameworks advanced in this research, in relation to an understanding of the thesis problem and how it may be resolved. As shown, the thesis problem and its resolution can be conceptualized both from a process design and a HCI perspective. Specifically, the thesis problem concerns both the HCI design of the existing Flight Plan (and in particular, the information provided to Flight Crew in the Flight Plan), along with the process design rules inherent in the sharing of operational and safety information across team agents and tools, at different points in the Flight Operations process to support the individual and collaborative task requirements of the process.

Critically, the analysis of the broader Flight Crew task illuminates the role of Flight Crew in terms of managing different levels of complexity and co-ordinating task and information inputs across different team agents involved in the Active Flight Operations process, and other processes that interface with this process. Further, an analysis of the Flight Crew task highlights the key role of information in terms of assessing the situation picture and identifying a course of action. As shown, this information is derived from Flight Crew interactions with different team agents and tools. Critically, the quality of tools and information available to Flight Crew shapes task performance and impinges on task outcomes. Moreover, the analysis of the broader Flight Crew task illuminates the relationship between Flight Crew information flow and the broader process design. As evidenced, the nature of the information provided to crew – both in terms of the human computer interaction (HCI) design of task support tools and the information provided by team agents – is determined by the underlying process design.

Thus, the analysis of the wider Flight Crew task sets the scene for the conceptualization of the pre-flight, flight planning and briefing task, and the associated analysis of Flight Crew task problems at the pre-flight stage. Moreover, this provides the theoretical basis for many of the requirements embedded in the Intelligent Flight Plan.

Following this, research findings in relation to Flight Crew performance of the pre-flight, flight planning and briefing task are discussed. This includes an analysis of the role of this task in relation to wider task activity, an analysis of performance shaping factors and an analysis of

the impact of these performance shaping factors in terms of task outcomes and consequences.

Thesis findings in relation to specific task problems and the origins of these problems are then reviewed. Here, specific process issues underpinning Flight Crew performance of the pre-flight, flight planning and briefing task and the HCI design of the existing Flight Plan are discussed.

Following this, the discussion moves to an analysis of how these problems might be resolved in terms of introduction of an improved electronic Flight Plan, and the parallel specification of new Flight Operations processes, allowing for improvements in information sharing across relevant operational functions at different points in the Flight Operations timeline.

The collective findings of this thesis in relation to the requirements for a good briefing are then discussed. Lastly, the Intelligent Flight Plan (IFP) concept is reviewed in terms of delivering on the requirements for a good briefing.

2. MODEL OF FLIGHT CREW TASK PERFORMANCE

Introduction to Flight Crew Task Model

As noted in Study 1, existing task models fail to provide a comprehensive account of Flight Crew task activity. These models focus on specific dimensions of Flight Crew task activity at different levels. Thus, a more integrated account of Flight Crew task performance is required. In general, these accounts present a 'local' description of Flight Crew task performance. That is, they provide an explanation of Flight Crew task activity in relation to specific cockpit interactions and procedures. Further, a theoretical explanation of certain non technical dimensions of Flight Crew task activity is provided. Several weaknesses in these accounts were identified. Existing accounts fail to elucidate the relationship between task and process. Also, the team picture appears inadequate. Many different accounts of the role of procedures in operations are provided. Further, existing models of Flight Crew task functions fail to capture the complexity of Flight Crew task activity in commercial operations. Moreover, these models accord insufficient attention to the role of reporting.

The Flight Crew task has been analysed at different levels, linking to the methodological design of the different studies. This has yielded a model of Flight Crew task performance at different levels. This includes: (1) a high level model of the socio-technical elements of Flight Crew task activity and their relationships, (2) a model of task performance in relation to different levels of process, (3) a model of task performance in terms of duty status, and (4) a model of Flight Crew role/task functions in terms of on duty task activity. Taken collectively, these different levels of task model yield an integrated account of Flight Crew task

performance. Arguably this 'joined up' account resolves certain problems with existing task models - specifically in relation to understanding the shaping influence of the process and other socio-technical elements (i.e. teamwork, context, tools and information), on Flight Crew task activity. In general, the proposed model reflects a shift from a local explanation of Flight crew task performance to a broader process based explanation. In so doing, this model illuminates the complex role of procedures in commercial operations. Moreover, this model highlights the requirement to reformulate existing Flight Crew task functions, to better capture the operational and organisational reality underpinning Flight Crew task activity.

Socio-technical aspects of Flight Crew Task performance

The findings of the first four studies suggest that Flight Crew task performance can be described in relation to several socio-technical elements. Core elements include: operational concept, process (i.e. Active Flight Operations process and other processes), duty status, role/task functions, task procedures, task activity, team, flight situation/context, task environment, information, and information flow. Other relevant elements include: regulation, airline goals and objectives, the airline's business model and the airline's safety culture.

The relationship between these different elements has been explored at different levels of detail in this thesis. Specifically, this research has focussed on the relationship between task and process. Within this overall framework, the team task performance requirements of the process and associated information/information flow requirements have been analysed. This is discussed in more detail in the next section.

Overall, it is argued that these socio-technical elements exist at different levels. In this respect a hierarchy of socio-technical elements is proposed. The nature of this hierarchy is outlined in Figure 31.

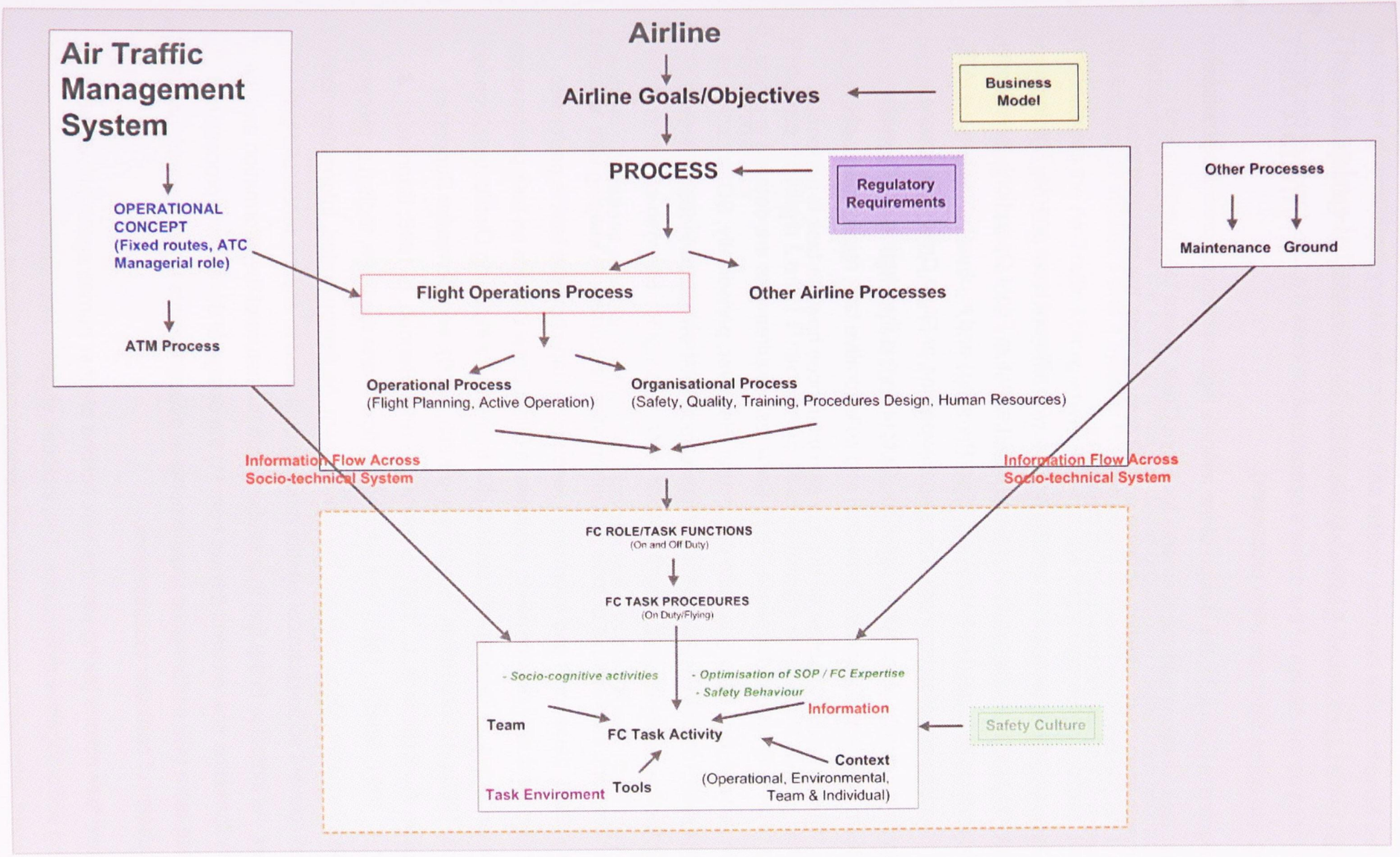

Figure 31: Socio-technical Analysis of Flight Crew Task (Discussion)

As indicated in Figure 31, airline operational and organisational processes are designed to achieve relevant airline goals/objectives. This includes commercial, operational and safety objectives. Specific airline business models and broader regulatory requirements impact on the design of these processes. Separately, the design of the existing operational concept has a bearing on the design of the airline's operational process (i.e. the design of the flight planning and active flight operation processes).

As highlighted in Figure 31, the design of the airline's flight operations process generates particular task functions and requirements for Flight Crew. These task functions and requirements span crew activities while on and off duty. Further, the design of these processes shapes how the crew perform their tasks.

Flight Crew execute relevant tasks in collaboration with different team agents. The team spans human agents working in the local process (i.e. Active Flight Operation), the broader Flight Operations process (i.e. Safety and Flight Planning) and in other processes (i.e. ATC, Ground Handling and Maintenance). The actual execution of Flight Crew task actions depends on the quality of team task activities. Critical here is the sharing of information across team agents to support the individual and collaborative task requirements of the process. The context or situation on the day also influences how the task is performed.

In terms of on duty task performance, Flight Crew task requirements are detailed in airline SOPs. In general, task activity is quite procedural. However, periodically, SOPs cannot be strictly followed. In such cases, Flight Crew draw upon their own experience/expertise, in deciding how best to optimise SOPs.

Task performance involves use of tools and information resources. In keeping with Norman's analysis (1988), these tools and information resources shape how the task is performed. Specifically, the quality of information available to Flight Crew impacts on task performance and task outcomes. In keeping with several HCI frameworks including Distributed Cognition (Hutchins, 1995a, 1995b, Hollan, Hutchins and Kirsh, 2000), and Computer Supported Cooperative Work (Bannon, L., 1991; Bannon, L., 1993; Bannon, L. 1998; Bannon, L., & Schmidt, K, 1991; Grief, I., 1988), this information flow spans the team, tools (i.e. electronic tools and information resources) and the environment. As demonstrated, information flow across all relevant socio-technical agents must be optimised to ensure successful task outcomes. As indicated in the first four studies, both the nature of the information and the broader information flow process follows from (1) the design of the existing process and associated team task performance requirements at different points in the process, and (2) the HCI design of particular tools/systems.

Flight Crew task actions (along with the task actions of other human agents) involve certain underlying socio-cognitive dimensions. This includes situation assessment, task management, information management and decision making. Further, Flight safety

objectives underscore Flight Crew task performance. This in turn is influenced by the airline's safety culture.

The Shaping Influence of Process Design on Flight Crew Task Activity

Introduction

This research highlights the shaping influence of the process on Flight Crew task activity. The findings of studies 1 and 4 indicate that the scope of these processes is quite broad. This includes the Air Traffic Management Process, the Flight Operations process, the Maintenance process and the Ground Handling process. Primarily the first four studies focus on the shaping influence of a subset of these processes, namely the three Flight Operations processes. The influence of the Flight Planning process and the Safety/Quality/Improvement process on Flight Crew task activity has been explored at a general level. However, the impact of the Active Flight Operations process on Flight Crew task activities has been explored in more detail.

Process 1: High Level Processes that Impinge on Flight Crew Task Performance

Process workshop findings demonstrate that several processes impact on Flight Crew task performance. As depicted in Figure 32, this includes the Air Traffic Management Process, the Flight Operations process, the Maintenance process and the Ground Handling process.

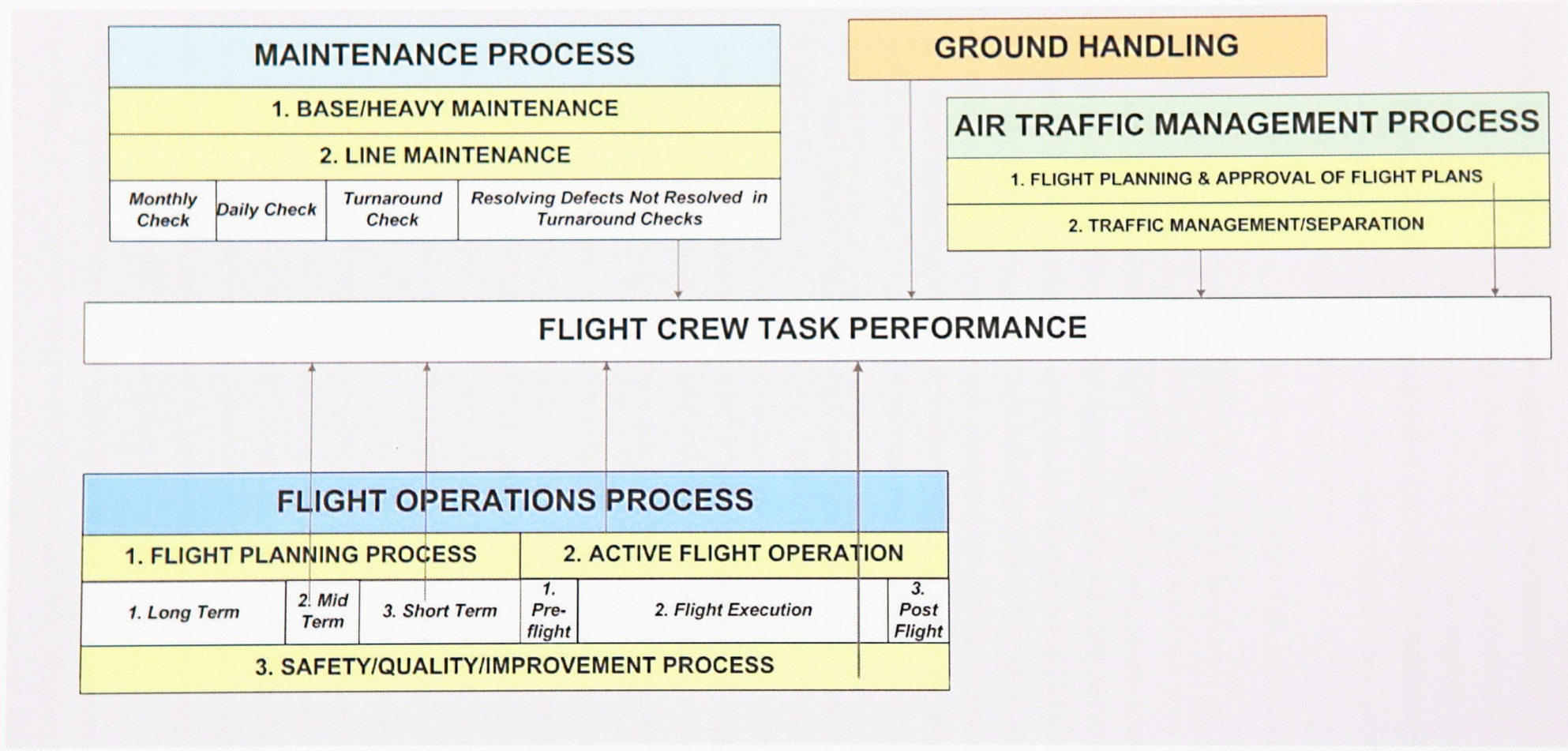

Figure 32: Scope of Process and Task Relationships (Discussion)

Consistent with the literature, the findings of studies 1 and 4 indicate that Flight Crew task performance is shaped by the overall Flight Operations concept, and the related ATC processes which support this. Critical here is (1) the signoff of the flight plan between ATC/Dispatch and (2) Flight Crew co-ordination with ATC throughout the flight operation. As highlighted in Study 1 and Study 4, last minute changes to the descent profile requested by ATC during the final approach necessitate re-briefing, thereby increasing crew workload and at a critical stage in the flight operation. Further, the design of airline flight operations processes has a bearing on the Flight Crew role. Specifically, these processes generate particular task requirements for Flight Crew. This includes the two operational processes (i.e. the Flight Planning process and the Active Flight Operations process), and the Safety/Quality/Improvement process. These were examined in more detail in studies, 2, 3 and 4. In addition, the design of Maintenance and Ground Handling processes impact on Flight Crew task activity. Periodically, Flight Crew experience flight delays related to the resolution of aircraft technical activities by Maintenance Engineers. As a consequence, tasks are often hurried, to recover lost time. This can impact on crew briefing activities, at the pre-flight stage. In addition, delays loading baggage and/or catering, and fuelling issues, can impinge on Flight Crew task workflows.

Process 2: Relationship between Flight Operations Process and Flight Crew Task

Overview

The relationship between Flight Crew task performance and the broader Flight Operations process was explored to different degrees in the first four studies. Firstly, this research points to certain relationships both between these processes and within certain processes. Further, it points to a relationship between the design of these processes and Flight Crew task activity. In particular, it highlights the degree to which the information flow logic embedded in the design of these processes, impacts on Flight Crew task activity. Primarily this information flow logic concerns the production of the flight plan, the sharing of operational information/updates across team agents related to the real-time flight operation, and the generation, review and management of Flight Crew reports, and associated safety analysis feedback loops.

High Level Process Relations (Across Flight Operations Process)

As indicated in Figure 33, there is a relationship between the different Flight Operations processes. This includes a relationship between:

- The Flight Planning process and the Active Flight Operational process (i.e. progressive specification of the Flight Plan)

- The Safety/Quality/Improvement process and the Flight Planning process (i.e. feedback about safety issues to be taken into account in Flight Planning)
- The Safety/Quality/Improvement process and the Active Flight Operations process (i.e. feedback about safety issues to Duty Manager/Flight Crew/Dispatch)
- The Active Flight Operations Process and the Safety/Quality/Improvement process (i.e. Flight Crew safety/human factors feedback provided in reports which populates relevant safety analyses)
- The Active Flight Operations process and the Flight Planning process (i.e. Flight Crew reports feedback concerning operational issues which is taken into account in the design of rosters and the production of the flight plan).

Figure 33 provides an overall depiction of the relationship between these processes and the information flow logic inherent in the design of these processes. As shown, this information flow logic primarily links to the advancement of the Flight Plan, the sharing of information between different operators linking to the execution of the flight operation, the generation of crew reports, the analysis of crew reports and the provision of safety feedback to different Flight Operations functions (i.e. Flight Planning, Dispatch and Flight Crew).

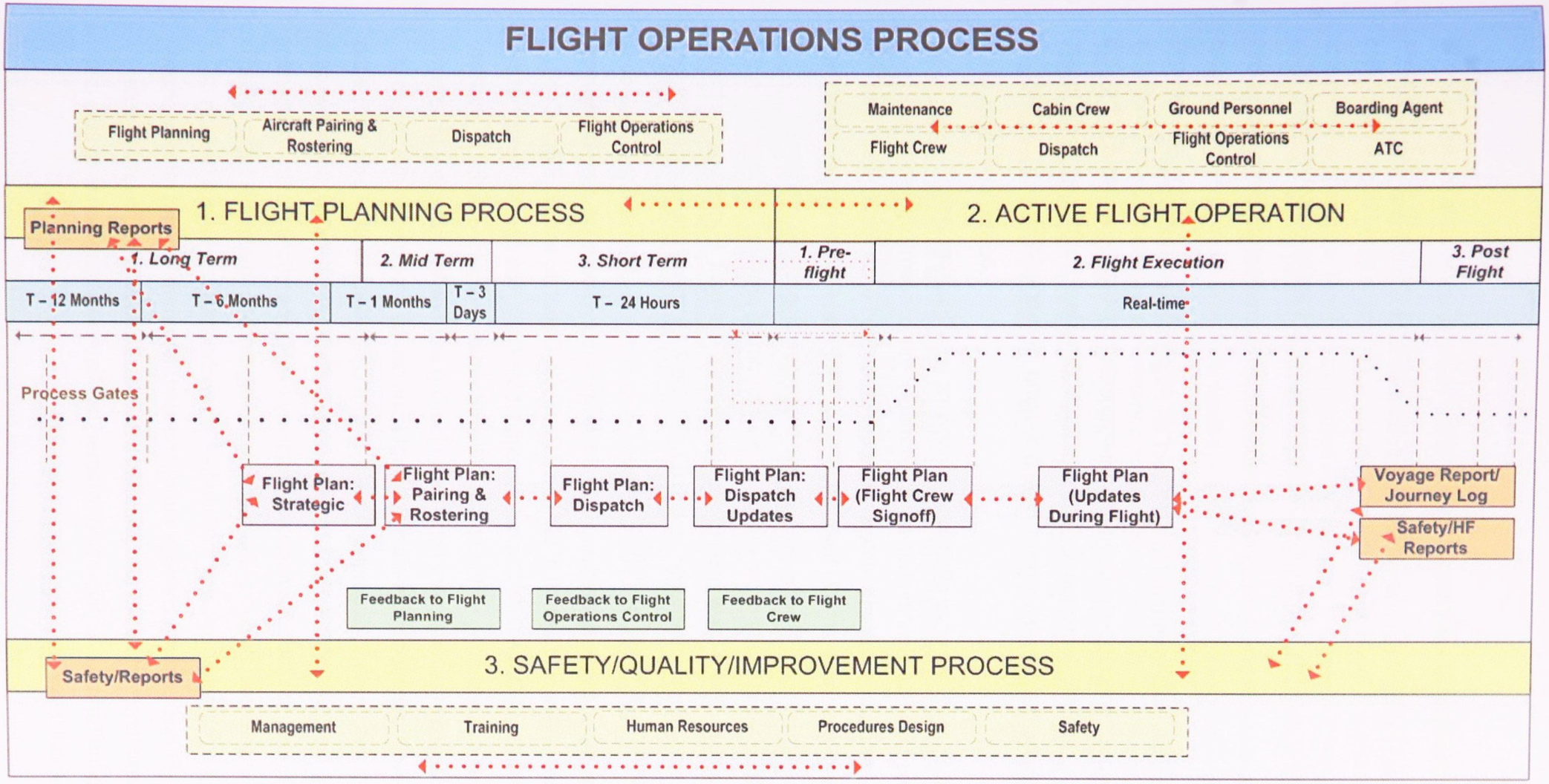

Figure 33: Flight Operations Process and Flight Crew Task (Discussion)

High Level Process Relations (Within Processes)

These studies also highlight several relationships/dependencies within these processes. This includes the

- Communication of safety findings from safety personnel to training/procedures design
- Decisions made by Flight Planning which impact on the production of the flight plan by Dispatch.

Process Relationships/Dependencies & Impact on Flight Crew Task Activity

Flight Crew complete specific tasks given the requirements of these processes. Further, this research points to specific dependencies between Flight Crew task performance and these processes. Critically, these dependencies have a shaping influence on Flight Crew task performance.

As evidenced in Study 2, the crew often inherit problems resulting from task decisions/actions made by planning personnel. Primarily, this concerns decisions/actions made during (1) aircraft pairing and rostering and the production of the high level Flight Plan by Flight Planning personnel, and (2) the production of the Flight Plan by Dispatch (i.e. the interface between the Flight Planning process and the Active Operations process). As evidenced in Study 1 and Study 4, the quality of the information provided by Dispatch in the Flight Plan impacts on Flight Crew briefing and situation assessment. Further, as illustrated in Study 3:2, the additional information provided by Airline 2 for crew flying complex routes, assists crew planning and briefing activities.

In relation to the Active Flight Operation, studies 1, 2 and 4 emphasize the shaping influence of (1) Flight Crew review and signoff of the Flight Plan with Dispatch, and (2) Flight Crew collaboration with Flight Operations Control throughout the flight. The specific design of the Dispatch process has a bearing on the nature of the information provided in the Flight Plan. This in turn impacts on the nature of Flight Crew planning and briefing activities. In general, many Flight Crew information/information flow problems can be attributed to the design of the dispatch process. Further, decisions made by Flight Operations Control both before the flight and during the course of the flight, have an impact on Flight Crew task performance. In relation to the former, this includes decisions made by Flight Operations Control concerning aircraft and crew changes, as part of the real time management of the global flight operation. As reported by participants in the first four studies, crew changes can have a bearing on team concepts. Further, aircraft changes during the aircraft turnaround and release phase, often result in less time for briefing and planning activities. In relation to the latter, route changes during the flight (i.e. to avoid bad weather) or alternate changes (i.e. to take into account commercial interests) necessitate re-briefing.

There is also a relationship between the Safety/Quality/Improvement process and certain aspects of Flight Crew task performance. Studies 1 and 3:1 illuminate the important role of crew reporting, in terms of providing feedback to Safety personnel concerning the safety/risk status of the operation. Further, as pointed out in Studies 1, 3:1, and 4, the provision of feedback from Safety personnel to Flight Crew, in relation to general/fleet level issues, or individual performance issues (i.e. flight feedback if a safety critical event occurs) has a bearing on task performance. This feedback is used to identify and understand potential flight threats and/or pitfalls, to learn about TEM strategies, and to improve their overall technical and non technical performance competencies. In addition, Studies 1, 3:3 and 4 suggest that Pilots actually apply certain CRM training concepts, in the active operation. This relates to the application of CRM behaviours (i.e. briefing and joint decision making), and the explicit practice of TEM behaviours. In this sense, crew training concepts influence Flight Crew task performance.

Process 3: Model of Flight Crew Task Performance in the Context of the Active Flight Operations Process

Overview

The findings of studies 1 and 4 provide an insight into the shaping influence of the Active Flight Operations process on Flight Crew task activity. Critically, an analysis of this relationship provides a means in which to interpret certain other socio-technical dimensions of Flight Crew task activity. As indicated in Figure 34, this provides a lens through which to understand (1) the relationship between task and team, (2) information flow across relevant team agents, (3) the influence of context on task activity, and (4) the role of procedures.

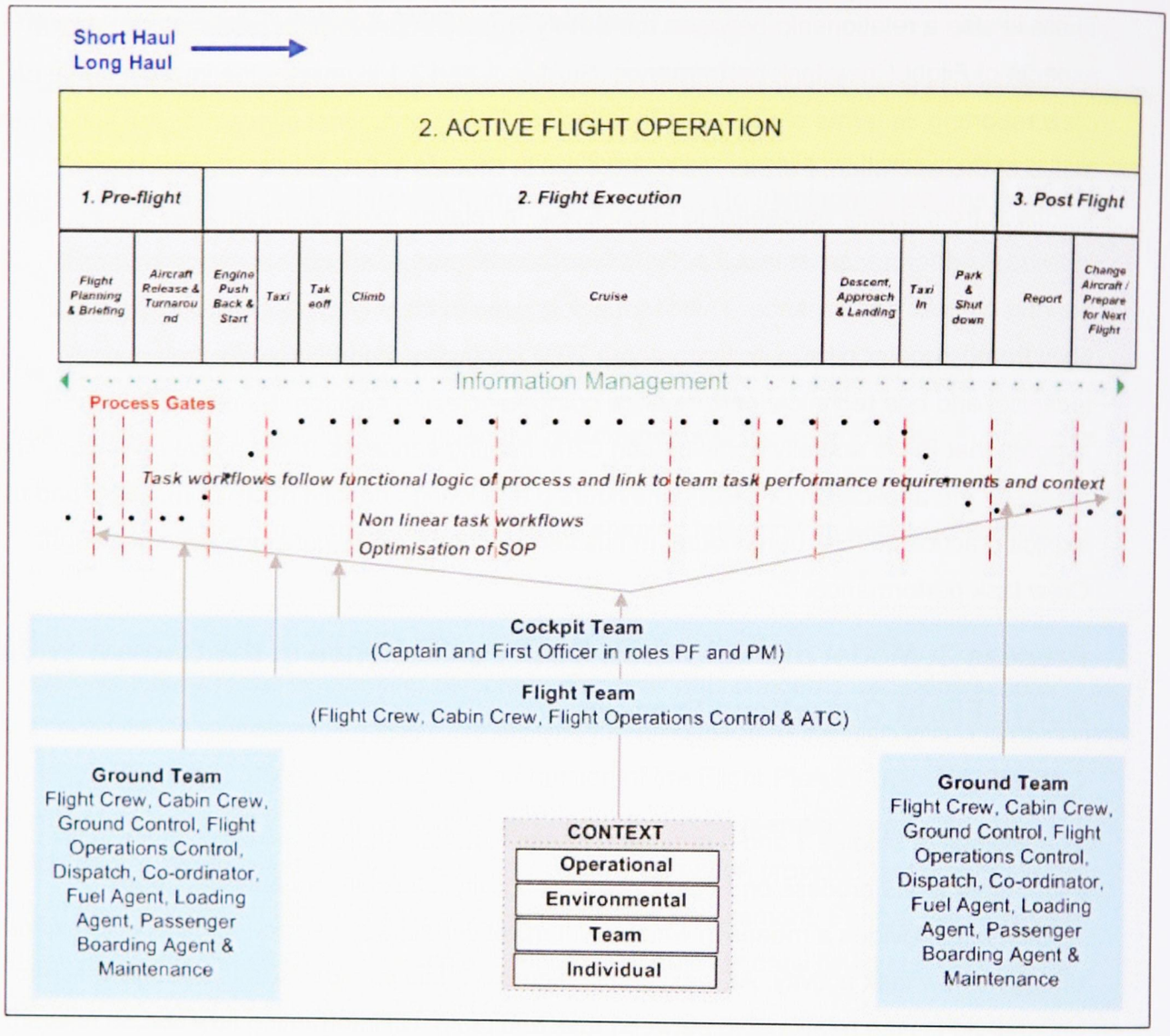

Figure 34: Flight Crew Task and Active Flight Operations Process (Discussion)

Process

This research indicates that the Active Flight Operations process (i.e. Flight Operations sub-process 2), is structured in terms of a series of (1) process phases (i.e. pre flight, flight execution, post flight), (2) process sub-phases (i.e. for the pre-flight phase this includes, flight planning and briefing and aircraft release and turnaround) and (3) process gates (i.e. for flight planning and briefing this includes: crew arrival/check in, crew briefing, crew combined briefing, and travel to aircraft). This links to a higher level process hierarchy (i.e. flight operations concept and Flight Operations process), as explored in the earlier analyses.

As established in studies 1 and 4, the functional logic of this process dictates Flight Crew task performance requirements and the nature of Flight Crew task workflows. Further, it sets the boundaries for Flight Crew collaboration with other team agents, and associated information sharing requirements. As shown, Flight Crew carry out a range of tasks at different points in the operational process, linking to the task activities of other agents involved in similar and different processes. Thus, the process is conceived as the key

structuring principle for Flight Crew task activity, as opposed to flight phases as defined in airline SOPs. As demonstrated in studies 1 and 4, it is critical that Flight Crew task requirements are managed such that necessary process states are achieved at different points in the process. In this sense, what matters from a workflow perspective is that key issues are managed, such that necessary tasks are executed in line with the requirements of the process. Overall, this has implications for Flight Crew task frameworks. Existing task models represent a Flight Crew centric perspective on task activity. Flight Crew task requirements are considered in relation to the performance of sets tasks at specific flight phases. This is perhaps justified, given that (1) Flight Crew act as an overall co-ordinating interface across a range of operational roles, and (2) their actions directly relate to aircraft states. However, airline SOPs fail to capture the process logic which underlies this task activity. Moreover, airline SOPs fail to capture the team dimensions of this activity, which is linked to the wider operational process picture and associated information flow requirements. For this reason, it is suggested that we move beyond Pilot/flight centred models of task performance. Overall, a process based model of Flight Crew task performance is proposed. This takes a more holistic/collaborative view on Flight Crew task performance – taking into account the collaborative requirements of the process while prioritizing the Flight Crew role.

Team

As stated above, the process logic generates specific collaboration requirements between Flight Crew and other operational agents at different points in the process. Flight Operations manuals primarily focus on a subset of these team agents. This includes Flight Crew, Cabin Crew and ATC. However, as demonstrated in studies 1, 2, 3:1 and 4, Flight Crew task performance involves strong collaboration with many additional roles. As depictured in Figure 6, this includes the Dispatcher, Flight Operations Control/Duty Manager, the Co-ordinator, Maintenance Engineers and others. Crucially, the task performance of the wider team has a bearing on Flight Crew task performance, in terms of workflow, workload and information requirements. As demonstrated in jump-seat observations with crews from Airline 2 and Airline 5, on certain occasions it is not possible for crew to commence a task and/or complete a task, because they are waiting for another role to complete a task, or to provide them with information. Moreover, the crew are regularly interrupted while completing their tasks. Again, this impacts on task workflows. This is particularly the case at the pre-flight stage. In general, this coheres with the findings of Loukopoulos, Dismukes and Barshi (2003), in relation to the impact of team task performance requirements on Flight Crew task activity.

Use of tools and information

In keeping with Hutchins (1995a, 1995b) analysis, and the research of Johnston (2003), Pilots use a range of both physical and non physical tools, as part of task performance.

Essentially, the myriad of tools assists either different aspects of the same task or different tasks. In this way, there is a relationship between the different tools insofar as they collectively support Flight Crew task performance. As demonstrated in studies 1 and 4, the crew interact with a range of paper and electronic tools throughout the flight timeline. These can be termed physical tools. Further, research indicates that Flight Crew task performance also involves the use of certain abstract or non physical tools. Studies 1, 3:3 and 4 provide examples of these tools. This includes: the crew members mental picture of the proposed flight, rules of thumb (i.e. if the weather is bad, then a full briefing is required), training mantras (i.e. first aviate, then navigate and then communicate), knowledge of procedures, prior experience of a situation, the application of specific CRM concepts (i.e. joint briefing) and TEM strategies. Significantly, these tools exist given the human contribution to work tasks, both on an individual and team level. Thus, the use of these tools depends on the cognitive and social makeup of both the individual crew members and the team taken collectively.

Flight Crew tools act as task aids on a number of levels. This includes providing information relevant to the task, facilitating the performance of certain tasks, and automating certain tasks. As highlighted in studies 1 and 4, the nature of the task and associated task workflows follows from the information provided by these tools. However, this in turn depends on the process design. Specifically, the process design dictates what information is provided to Flight Crew and how this is communicated to Flight Crew. This is well illustrated in the terms of the Flight Plan. Moreover, research indicates that the quality of tools and information impinges on task outcomes. If information is unavailable or not current, crews cannot complete their task. In such situations, crews are required to continuously monitor the status of this information. This necessitates additional effort on behalf of the crew in terms of information monitoring and task management. These situations are often stressful for crew. Further, this can impact on the completion of other tasks. This in turn has an impact on the overall achievement of the operational goal.

Context/Flight Situation

The finding of studies 1, 2, 3:2 and 4 indicate that the flight situation and/or context impacts on the nature of Flight Crew task requirements and workflows. As reported, the process of getting from A to B involves more than following a pre-defined Flight Plan, taking into account any flight plan changes requested by ATC. Individual flights are characterized by different levels of operational and environmental complexity. Overall, this impacts on Flight Crew task performance requirements, workflow and workload. Further, as pointed out by Flight Crew participants across studies 1 and 4, the safety outcome depends on how well crew manage the different operational and environmental issues which arise on the day.

As illustrated in Figure 34, context can be conceptualized in terms of four overall factors. This includes (1) operational factors, (2) environmental factors, (3) Flight Crew team factors and (4) individual factors. Operational factors include passenger issues, aircraft changes and crew changes. Environmental factors include: the complexity of the routing, weather issues and ATC changes/issues. The team context refers to crew familiarity, crew familiarity with the route, the combined crew member's fleet experience and the quality of the team briefing. Lastly, individual factors include the individual crew member's duty status, fatigues levels, fleet experience, training background and route experience.

This has implications in terms of existing workflow models (i.e. flight phase/procedural models). It is argued that the SOP/flight phase approach reflects an idealized notion of Flight Crew task activity. Arguably, it has resulted in generic workflow accounts which describe task activity as consisting of a set of tasks performed in an ordered fashion. With the exception of the task models proposed by Loukopoulos, Dismukes and Barshi (2003), there seems a tacit acceptance of these linear workflow models. In support of Loukopoulos, Dismukes and Barshi (2003), research demonstrates that task execution does not follow the linear workflows as defined in airline SOP's. Arguably, these models fail to capture the sense in which the context at the time has an impact on whether certain tasks can be performed at the optimum time in the process. As established, it is not always possible for crew to perform tasks at fixed times, as detailed in SOP. Rather, research reveals that crew juggle many concurrent tasks, at different levels of completion, depending on the situation. In this sense, SOPs describe the ideal workflow (i.e. how tasks might be performed assuming minimal complexity), at set points in the flight. This is different to the actual workflow (i.e. how tasks are actually performed given the situation on the day). Thus we must move beyond linear task workflow accounts. This is not to suggest that Flight Crew task workflows do not follow any underlying logic. As demonstrated, the functional logic of the process dictates Flight Crew task workflows. At certain key points in the process (e.g. process gates), specific tasks must be accomplished, or the process cannot move forward.

Procedures

This research poses certain challenges to procedural task models. As noted previously, given task interruptions and delays obtaining information, it is often not possible for Flight Crew to follow the prescribed workflow as defined in airline SOPs. Further, periodically, flight situations are indeterminate, and it is not always possible, or advisable, to follow procedures. In such situations, Pilots draw upon their prior experience and expertise, in making an assessment of the situation, and identifying the best course of action. As illustrated in the Alta scenario, this may involve the improvisation of procedures. The Alta scenario is interesting precisely because it illustrates that wilful non compliance is sometimes appropriate. As demonstrated, safety is bolstered by optimizing procedures (or breaking with procedures) and flying a different glide scope angle. However, such a tactic is not always

acceptable. Failing to follow procedures because of complacency or forgetfulness presents a real safety threat. As discussed in Study 1, existing task models explore issues related to the use of expertise (Johnston, 2003) and improvisation. However, they do not explore specific issues related to Flight Crew optimization of procedures. In this way, the Alta scenario provides a real world example of the application of expertise in relation to the optimisation of procedures.

As noted in Study 1, various different accounts of procedural drift have been provided. In keeping with the findings of Losa (2007), this research suggests that the reasons for procedural drift go beyond the issue of crew complacency. Critically, procedural drift can be linked to process design. Studies 1 and 4 demonstrate that given weaknesses in the existing process design concerning the sharing of operational information between team agents, the crew are often required to engage in informal information gathering activities not defined in SOPs.

Flight Crew Duty Status & Task Requirements

Implicit in the analysis of the relationship between the Flight Operations process and the Flight Crew task is an analysis of Flight Crew task performance in relation to the crew member's duty status. The foregoing research suggests that the Flight Crew duty status is a key organising principle for conceptualizing Flight Crew task activity. Flight Crew perform specific tasks while on and off duty. As demonstrated in Figure 35, these duty requirements span two Flight Operations processes. This includes the Active Flight Operations process and the Safety/Quality/Improvement process.

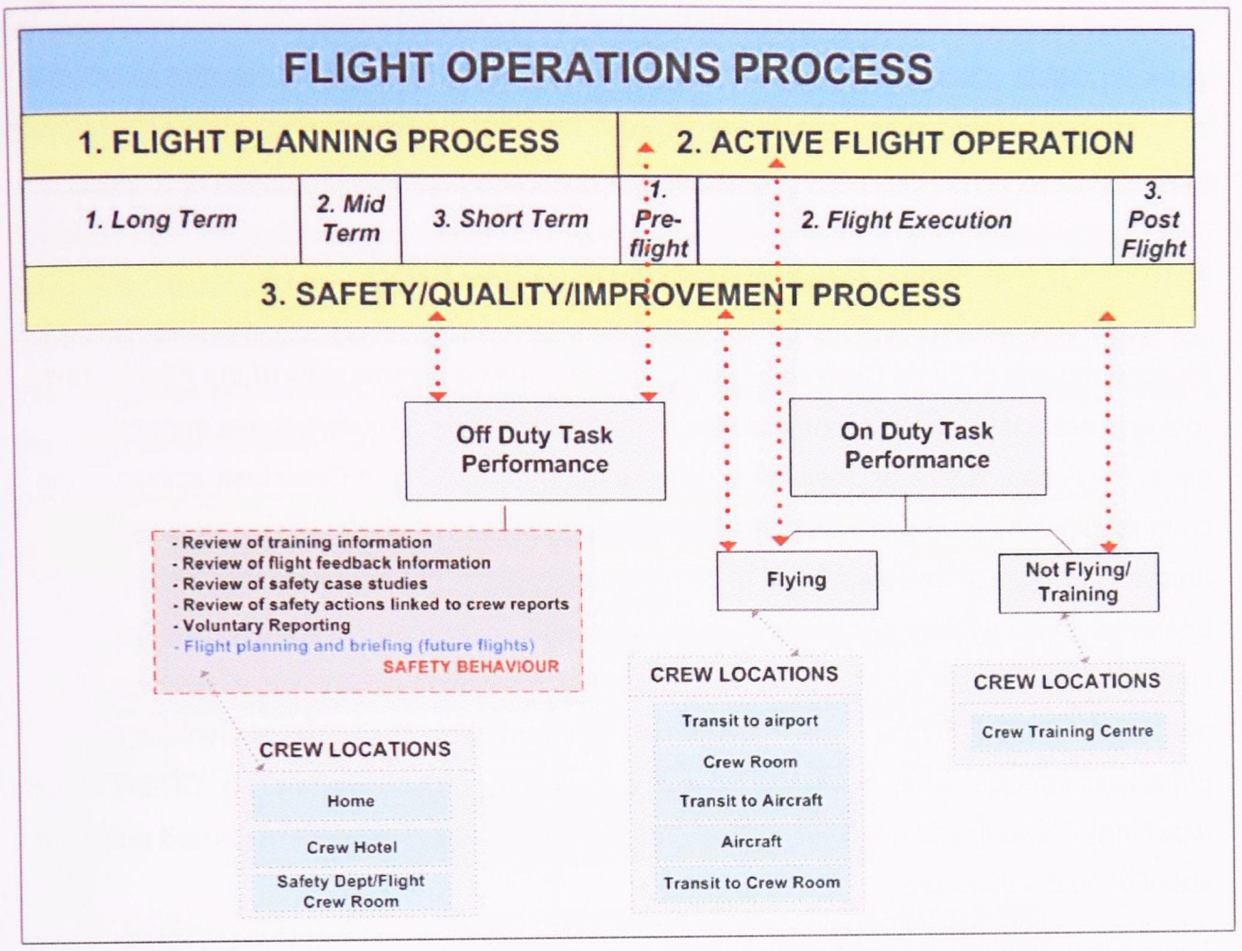

Figure 35: Flight Crew Duty Status & Task Requirements (Discussion)

Two further organising principles, linking to the concept of duty status are also defined. This includes the crew's physical location (both on and/or off duty), and the crew's location in the active operational process (if on duty). The concept of crew location links to (1) the crew duty status and (2) the crew position in the Active Operational process. Several task environments/locations and associated task requirements have been identified. This includes: the crew room, the aircraft, the crew training centre, the crew hotel (i.e. if an overnight is required as part of the crew's duty schedule) and the crew member's home. Further, the crew may be in transit from one location to another (i.e. from the crew room to the aircraft, from the aircraft to the crew room, from one aircraft to another and/or from home to the crew room).

The findings of Study 1 and Study 4 indicate that Flight Crew safety behaviour spans both on duty and off duty task performance. Off duty safety behaviours are not formally defined in airline SOP. Further, the safety literature tends to overlook these activities. Primarily, off duty safety behaviour relates to voluntary reporting activities. As demonstrated in Study 1 and Study 4, in addition to reporting, Pilots periodically review safety case studies both at a general and fleet specific level. This information is accessible both online (i.e. crew intranets/websites) and from crew safety magazines and news bulletins. Moreover, Pilots frequently conduct preparatory briefing sessions in advance of the flight, from home and/or

their hotel room (i.e. if their duty schedule requires an overnight stay). This is particularly the case, for flights with complex departure and/or arrival procedures. Critically, this dimension of safety behaviour is not currently supported in terms of the design of existing Flight Crew tools.

Flight Crew Role/Task Functions (On-Duty)

Existing models of Flight Crew role task functions reflect a narrow view of the Flight Crew role and associated task responsibilities. In many ways, these models make sense for general aviation. However, they fail to capture the nature of Flight Crew task activity in the commercial context. Significantly, there are certain differences between Flight Crew functions in each of these settings. In commercial aviation, the crew manage a complex operation involving different levels of operational and environmental complexity. This involves considerable collaboration with personnel involved in similar and different processes. Central to this, is the management of information. Further, this involves the practice of specific safety behaviours (i.e. application of procedures, briefing, CRM/TEM and reporting). Reporting is a key Flight Crew function. However, this is not accorded sufficient attention in the literature.

Thus, it is proposed that existing Flight Crew task functions be reformulated. A synthesis of the foregoing research suggests that Flight Crew task performance while on duty can be conceptualized in relation to the following role/task functions: (1) flight management (2) the management of operational and environmental complexity, (3) team management and (4) reporting. Underlying these functions is a further task function namely (5) task management. This formulation reflects a reconfiguration of the existing definitions provided by Abbott and Rogers (1993), and by Johnston and Ricks (1993, 1995). It is argued that this formulation better captures the socio-technical nature of the Flight Crew role. In particular, it both captures and elucidates the operational and organisational reality underpinning Flight Crew task activity.

So what is the nature of each of these proposed functions and how do they relate? Flight Crew task performance necessitates the transport of passengers from one location to another. In this regard, it involves the core function of flying the aircraft in accordance with the Flight Plan. This comprises two overall sub functions; namely aviate and navigate. Critically, the broader process logic (i.e. current flight operations concept and related ATC process, and current flight operations process) determines the specific nature of these functions. Further, as highlighted in Study 1 and Study 4, the functional logic of the process necessitates the performance of specific aviate and navigate tasks at particular process gates. In transporting the passengers from one location to the next, Pilots manage different levels of operational and environmental complexity. This necessitates the performance of

relevant safety/CRM tasks (i.e. briefing and TEM). Overall, this is in keeping with CRM frameworks (Johnston, 2003), and especially, the conception of Flight Crew task performance, as proposed in the TEM model (Helmreich, 1999). As established in Study 1 and Study 4, in executing the flight operation, Pilots collaborate with a range of human roles to obtain task and information inputs necessary to the performance of their tasks. As such, there is a relationship between the first three functions. This relationship is indicated in Figure 36. Reporting is also conceived as a key function. As evidenced in studies 1 and 4, this comprises both operational and safety reporting. However this function is independent of the three other functions, as depicted in Figure 36.

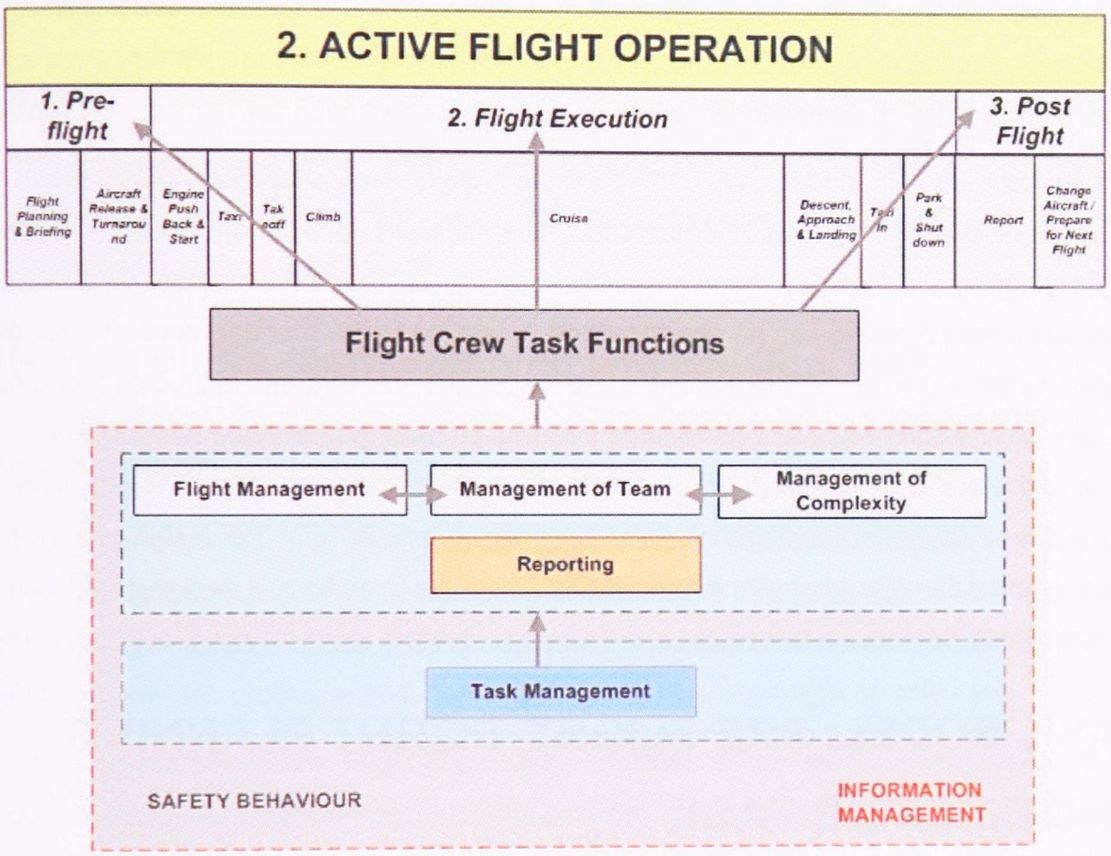

Figure 36: Flight Crew Role Task Functions (Discussion)

Flight Crew task performance includes a further high level function - task management. As demonstrated in Study 1, the transport of passengers from one location to the next, involves the monitoring and management of tasks in relation to the broader operational process. Flight Crew must ensure that task workflows correspond to the functional requirements of the process, at specific process gates. Thus, task management involves the ongoing tracking of both individual and team performance, in relation to the current and future situation. This monitoring spans tasks performed by (1) the crew member/oneself, (2) by the co-pilot, (3) by other operational agents and (4) by technical agents. As such, this goes beyond the crew centric definitions of task management proposed by Abbott and Rogers (1993), Johnston and Ricks (1993, 1995) and Funk (1991, 1998).

As indicated in Figure 36, Flight Crew performance of these task functions can be understood from two related perspectives. This includes safety behaviour and information management. As depicted in Figure 36, safety behaviour is conceived as implicit in everything that the crew do. However, safety behaviour also involves the execution of specific tasks. This includes briefing, TEM activities, checklist execution and reporting. For the most part, Flight Crew safety behaviour is conceived as implicit the first three functions, namely (1) flight management, (2) management of operational and environmental complexity and (3) team management. Both briefing and CRM/TEM behaviours link to flight management, the management of operational complexity and team management. Further, Flight crew optimisation of procedures relates to the management of operational complexity. Nonetheless, reporting is not implicit in any of these functions. As such, it is defined as a separate task function.

For the safe achievement of the operational goal, the crew perform a range of information management tasks linked to each of these functions at different points in the process. In this way, information and information management is implicit in all of these functions. As such, the Flight Crew task problem can be characterized in relation to the management and use of information pertaining to these task functions. As reported by participants in studies 1 and 4, Flight Crew information needs and associated information management behaviours vary according to the particular task performed. However, the management of these information needs and associated information management strategies follows from the design of the broader operational and organisational process and from the specific HCI design of existing task support tools.

3. TASK MODEL: PRE-FLIGHT, FLIGHT PLANNING AND BRIEFING TASK

Role of Briefing Task in relation to Broader Flight Crew Task

The first four studies highlight the critical role of the pre-flight, flight planning and briefing task in relation to the management of different levels of operational and environmental complexity. As part of the pre-flight, flight planning and briefing task, Flight Crew collaborate with a range of agents involved in similar and different processes, to obtain information necessary to the assessment of the flight situation and the associated management of complexity. In so doing, the crew obtain both task and information inputs from ATC, Maintenance, Ground Handling, Flight Operations Control/Duty Manager, the Co-ordinator, Dispatch and Safety. In this way, this task serves as an interface between Flight Crew and the Active Flight Operations processes and other processes. Further, the pre-flight, flight planning and briefing task is important from a workload management perspective. To unpack

this, we must refer to the concept of task dependencies and the distinction between task completion and task quality which emerged in Study 1. The briefing task may be completed, in the sense that SOPs may have been followed. However, a detailed analysis of both existing and potential future threats and how they might be managed may not have been undertaken. In this case, the requirements for a detailed briefing following CRM principles (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b) may not have been met. If the crew are well briefed at this time (i.e. a full and complete briefing is undertaken), then they are in a better position to manage both existing and/or potential future threats, if they emerge later in the process. Conversely, if the crew are not well briefed (i.e. complete briefing but not of high quality or incomplete briefing), both existing and potential flight threats may not have been examined. As such, weaknesses in the pre-flight briefing may make the management of these threats more difficult, if they arise at a later point in the process. Moreover, the performance of this task has an impact on the team formation and the overall quality of team relations.

Nature of Pre-flight Planning and Briefing Task

Introduction

The advancement a high level model of Flight Crew task activity has been useful in terms of developing a conceptual framework for interpreting the nature of Flight Crew task activities at the pre-flight stage. Further, it has been useful in relation to the conceptualization of specific Flight Crew task problems and their origins, and how they might be resolved.

As discussed previously, Flight Crew task performance has been conceptualized from an overall socio-technical perspective. This provides an analysis framework, in which to understand the nature of the pre-flight, flight planning and briefing task. As indicated, this task can be analysed in relation to several core socio-technical elements. This includes: process, teamwork, context, and tools/information resources.

Primarily, this research provides an account of the pre-flight, flight planning and briefing task in the context of the Active Flight Operations process. The Active Flight Operations process commences with Flight Crew performance of the pre-flight, flight planning and briefing task. The quality of this task has an impact on the performance of subsequent tasks. This is discussed in more detail in the next section. Flight Crew performance of this task, also links to certain wider Flight Operations processes. As remarked earlier, the crew often experience problems arising from decision made in the Flight Planning process. Largely, this concerns decisions made in the aircraft pairing and rostering process and the dispatch process. Further, dependencies were noted in relation to the Safety/Quality/Improvement process.

As part of task performance, the crew gather and review all information necessary to an assessment of the risk status of the operation and any required changes to the Flight Plan (i.e. fuel figure and routing). This necessitates interacting with relevant people involved in the same and different processes. As such, this task plays a key role in relation to Flight Crew coordination/management of the process.

This task fulfils certain key operational and safety requirements of the process. The review of flight information and the associated fuel decision is a key step in the operational process. Without this, the process cannot continue. Further, this task is essential from a safety management perspective. As shown, the key safety outputs of this task – namely teamwork, joint situation assessment, joint decision making and workload management - underpin the safe achievement of the operational goal.

As illustrated in field research with Airline 2 and 5 in Study 4, short haul crews may meet for the first time at the pre-flight stage. Depending on the roster, the crew may only fly one or more flights together. The crew may be from different cultural backgrounds, or have had different training backgrounds (e.g. military or civil). To this extent, they may have different expectations of flight roles, or different understanding of flight information. Thus, as highlighted by Clark (1996), it is important that the crew find a common ground which is a prerequisite for teamwork. Nonetheless, both crew disposition to make a briefing, and the quality of the briefing cannot be taken for granted. As evidenced in studies 1 and 4, the crew do not always perform a full briefing. This is discussed in more detail below.

As shown in studies 1 and 4, existing SOPs fail to provide a complete description of task activity. Typically, the crew are involved in many informal information gathering activities, to obtain the latest operational and safety information. These informal task activities arise, given weaknesses in the existing process design, pertaining to what information should be shared between team agents, as set points in the process. Further, as evidenced in studies 1 and 4, Flight Crew task activity at the pre-flight stage, does not always follow best practice in briefing, as emphasized in CRM theory (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b).

Three different briefing contexts were identified. This includes: briefing for the current flight, for the next flight, and for future flights. Flight Crew task workflows and the depth of the briefing vary according to the specific context. In relation to the current flight, an advance briefing is often performed by the First Officer before the official briefing commences. Flight Crew often perform an informal briefing for the next flight while in cruise. Lastly, both crew members often perform a preliminary briefing for future flights – and in particular flights with complex approach/departure procedures - while off duty.

Task environments vary. Primarily this includes the crew briefing room and the aircraft cockpit. However, certain informal task environments associated with informal briefing activities were identified. This includes the crew member's home, the crew hotel and crew transport vehicles (i.e. ferrying the crew to and from an aircraft or from the crew hotel to the airport).

The identification and analysis of both existing and future flight threats and the associated application of TEM concepts, is a key dimension of the pre-flight, flight planning and briefing task. As highlighted study 4, threats can be grouped into three overall categories. This includes: crew, aircraft and environment. It should be noted that this taxonomy reflects the views of a small number of Pilots from Airline 5. As such, it is not necessarily representative of the broader Pilot population. Further, flights are typically classified in relation to three risk levels - good, bad, and in-between. This does not always follow a rational process. Typically, this involves a level of pattern matching in relation to what is perceived as a good, bad, or in-between situation. Although this research uncovered information concerning the characteristics of each of these types of situations, further research is required in relation to unpacking the nature of this process.

Performance Shaping Factors (PSF)

Overview

As stated in the introduction to Chapter 3, the local actions of the flight crew are affected by a variety of immediate influences or performance shaping factors (Miller and Swain, 1987). Collectively, the first four studies highlight several factors which impact on how the task is performed. As noted previously, Miller and Swain (1987) distinguish factors which are primarily external to the individual and factors which are primarily internal. This research suggests an alternative (albeit somewhat similar) conceptualization of PSF's. For analysis purposes, these PSF's have been grouped into two categories: (1) socio-technical factors and (2) human factors dimensions. Broadly, 'socio-technical factors' correspons to Miller and Swain's (1987) 'external factors'. Conversely, 'human factors' correspond to 'internal factors'.

Socio-technical Aspects

Relationship between task and process

As highlighted in studies 1 and 4, the design of the dispatch process has a bearing on how this task is performed. Particular variations in the nature of the dispatch process (i.e. auto dispatch using computer or person to person dispatch using paper) were identified in Study 1. These influence how the task is performed in terms of team interactions and the use of tools and information. Further, as indicated in studies 1 and 4, the design of the process impacts on the time allocated to crew to perform the task.

Relationship between task and context

This research also illuminates the impact of the flight context (or flight situation) on the Flight Crew task. As evidenced in studies 1, 2 and 4, the nature of the dispatch process varies depending on risk status/complexity of the flight. For high risk flights, the Dispatcher and/or Flight Operations Control are involved in the pre-flight briefing. Also, the crew accord more or less time to this task depending on the perceived complexity of the flight. As indicated in studies 1 and 4, a more detailed briefing is undertaken if the weather is bad. The flight is a dynamic process. Operational and environmental changes have an impact on task requirements and task workflows. Such changes often result in the requirement to re-brief on certain aspects of the flight, or to perform a full re-briefing. In addition, delays obtaining information in relation to such changes can result in delays performing the briefing.

Collaborative nature of this task

Flight Crew collaboration with different team agents has a bearing on how the task is performed, and the specific nature of the briefing. As noted previously, for medium and high risk flights, the team concept is extended to include the Dispatcher and/or Flight Operations Control. The requirement to interact with these agents, changes the nature of the briefing and associated decision making, along with the depth of the briefing. Task interruptions from different team agents (e.g. the Fueller, Cabin Crew and Maintenance) often necessitate that the crew re-brief on certain aspects of the briefing. Separately, delays obtaining information from different team agents, can delay the briefing, and/or impact on the running order of the information review.

Relationship between task and tools

As evidenced in studies 1, 2, 3:2 and 4, the nature of the pre-flight, flight planning and briefing task, is shaped by the specific design of the Flight Plan. Crucially, the availability, quality and accuracy of information provided in the Flight Plan, impacts on the quality of Flight Crew situation assessment activities. As highlighted in Study 3:2, the additional briefing information provided by Airline 2 in relation to crews flying the Alta approach, enhances crew TEM and briefing activities. Further, the particular medium used (i.e. paper or electronic tool) can make it more or less easy to access information. Moreover, the design of the Flight Plan (i.e. layout of information), can make it more or less easy for Flight Crew to assimilate information.

Human Factors/Crew Dimensions

Across the first four studies, several human factors issues were identified which have an impact on the crew's disposition to brief, the depth of the briefing and the specific level of collaboration between crew members. Crew familiarity with the route can lead to complacency in relation to the requirement to conduct a detailed briefing. Flight Crew

familiarity can also impact on the crews willingness to make a briefing, the quality of the briefing and the level of collaboration between the cockpit team. As illustrated in jump-seat observations with Pilots from airline 5, the crew were familiar with each other and there was strong collaboration between both crew members. This situation was conducive towards making a briefing and joint decision making in relation to the management of flight threats. Further, the attitude of the Captain has an impact on the level of collaboration between crew members. As highlighted in Study 1, certain Captains can be more or less disposed towards teamwork and the requirement to make a joint briefing. This is often linked to the crew background (i.e. civil or military). Across the process workshops, participants noted that older Captains from a military background are typically (although not always) less disposed towards CRM concepts, given their training and past experience with a more hierarchical cockpit structure. Lastly, it was noted that crew fatigue can impact on crew situation assessment and decision making.

Conceptualising the Impact of Performance Shaping Factors

The impact of these performance shaping factors can be conceptualised at different levels. This includes: (1) impact on how the local task is performed (i.e. impact on the performance of the pre-flight, flight planning and briefing task), (2) impact on task outcomes, (3) consequences for subsequent Flight Crew tasks, (4) consequences for the flight operation and (5) broader operational consequences. This overall framework is depicted in Figure 37.

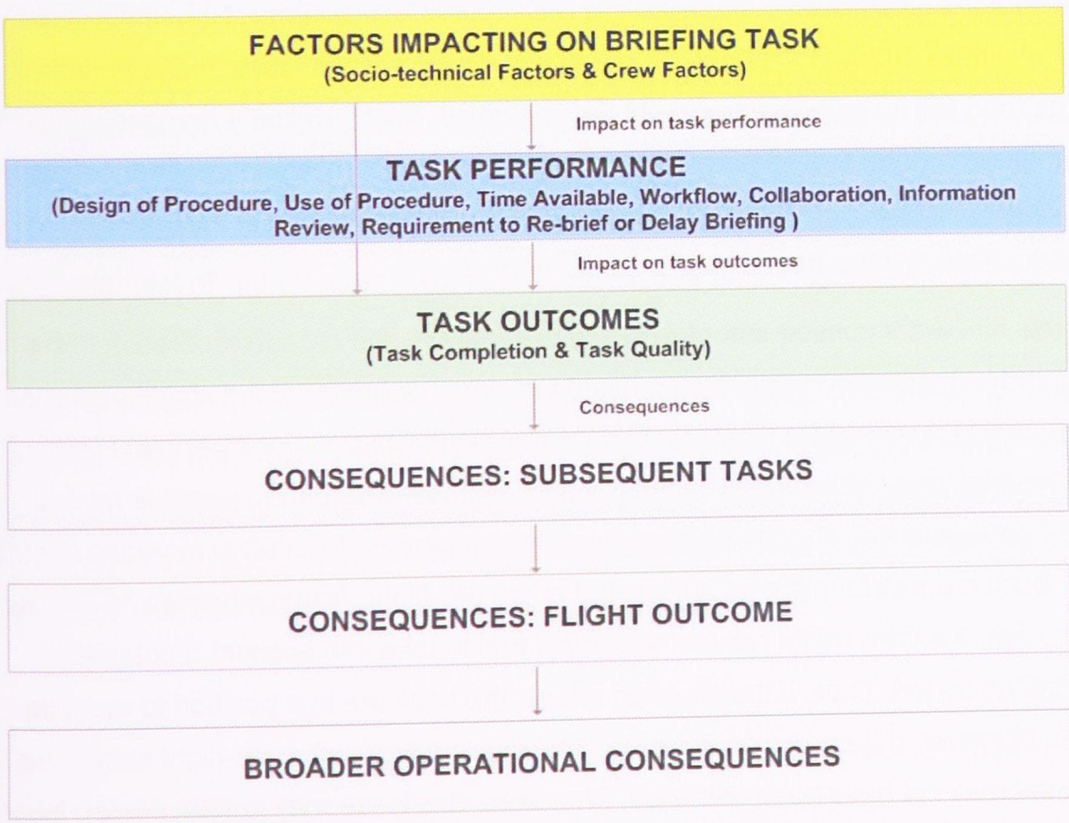

Figure 37: Conceptualising the Impact of Performance Shaping Factors on the Pre-flight, Flight Planning & Briefing Task (Discussion)

As outlined earlier, the different performance shaping factors influence how task is performed. To summarize the preceding section, this impact can be understood in relation to the design of the procedure, the task workflow, the time available to perform the task, task duration, level of collaboration between cockpit agents, level of collaboration between cockpit agents and other team agents, quality of teamwork, use of information, task interruptions, the requirement to perform a partial re-briefing, the requirement to perform a full re-briefing and task delays. These performance shaping factors also influence task outcomes. This can be conceptualized in terms of the completeness of the briefing and the quality of the briefing. As indicated in Figure 37, these task outcomes have consequences in terms of Flight Crew performance of subsequent Flight Crew tasks and in terms of the overall flight outcome. As highlighted in studies 1 and 4, the quality of the pre-flight, flight planning and briefing task, has an impact on Flight Crew performance of other formal and informal briefings that the crew undertake. Further, it has an impact on other tasks in terms of Flight Crew management of complexity, situation awareness and workload management. This in turn has an impact on the overall flight outcome. This includes the operational outcome and the safety outcome. In terms of the safety outcome, a range of potential outcomes can be considered. This includes: a safe flight within SOPs, a safe flight that does not conform to SOPs, a near miss and/or a safety critical incident. Broadly, this conceptualization follows from the concept of task dependencies which emerged in Study 1 and which was later validated in Study 4. Thus, in support of O Hare (2006), we might argue that these PSFs are considered to increase the likelihood of human error. Nonetheless, as highlighted in studies 1, 2 and 3, poor PSF conditions do not always result in unsafe acts or incidents. As reported by participants across these studies, Pilots routinely manage different levels of complexity. Further, this varies according to the competency and experience of the individual crews. In this way, the impact of these PSF's on the operational and safety outcome of the flight is difficult to measure and/or predict.

Moreover, this has wider consequences in terms of impact on the broader operation. Here, we must consider the relationship between Flight Crew management of the single operation and the management of multiple flights by Flight Operations Control. For example, Flight Crew may experience a holding delay in the approach phase arising from weather related problems (i.e. low visibility), and the allied regulatory requirement for ATC to increase aircraft separation. Such a problem might be anticipated in the pre-flight, flight planning and briefing session. As such, the crew might request additional fuel to take into account a potential extended holding period. Thus, if the situation arises, the crew are in a position to manage the problem. However, depending on the quality of crew briefing at the pre-flight stage, this potential threat may not have been identified. Therefore, this issue may not have been taken into account in terms of the fuel decision. Potentially, this problem will be identified and managed at a later point in the process. At this time, it may be difficult for Flight Crew and/or

Flight Operations Control to solve the problem in an operationally efficient manner. We might envisage a situation in which the crew are required to divert to an alternate, given extended holding requirements and insufficient fuel. This has an impact on the single flight and on the management of multiple flights by Flight Operations Control (i.e. the overall management of the operation). In terms of the single flight, the flight will be delayed and the passengers and crew will need to be transported to their required destination. In terms of other flights, there may be a requirement for a new aircraft and new crew to maintain the schedule. Further, delays may ensue.

Conclusions

The pre-flight, flight planning and briefing task plays a key role in terms of delivering on key operational and safety requirements of the process. The pre-flight, flight planning and briefing task supports Flight Crew management of complexity and the associated co-ordination of information inputs across different team agents and tools. The pre-flight, flight planning and briefing task is also essential in terms of cementing team concepts, supporting team situation awareness and managing workload. In relation to the latter, the quality of task performance at this time has a bearing on subsequent Flight Crew tasks. Moreover, this task is important from an operational perspective. The signoff of the flight plan is a key step in the operational process. In addition, this task functions as a key interface between the management of the process by Flight Crew and the wider management of the process by Flight Operations Control.

The application of TEM concepts as defined in CRM theory (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b) supports the identification and management of flight threats. This in turn has an impact on the safety and operational outcome of the flight.

Flight Crew task activities at the pre-flight stage do not always follow SOPs. Frequently, the briefing does not follow best practice in briefing as defined in the CRM literature. Often the crew are involved in informal workarounds, to gather necessary information from different team agents involved in the Active Flight Operations process and other processes that interface with this process.

4. PRE-FLIGHT FLIGHT PLANNING & BRIEFING TASK: TASK PROBLEMS, ORIGINS OF THESE PROBLEMS, RESOLVING TASK PROBLEMS & REQUIREMENTS FOR NEW TOOL

Introduction

The first four studies point to the socio-technical nature of Flight Crew task performance. Critically, they provide a picture of actual task performance and not simply SOPs. In so doing, they illuminate the many informal information gathering activities that Flight Crew are involved in, in order to obtain the latest information relevant to their flight and to assess the risk status of their flight. Further, these studies provide feedback about the specific task problems encountered by Flight Crew at the pre-flight stage and the origins of these problems. These studies also provide preliminary recommendations in terms of how these problems might be ameliorated via the introduction of an enhanced briefing tool and allied process redesign changes. Studies 5 and 6 suggest a specific way forward in terms of resolving these problems, in relation to the introduction of an improved safety management and intelligent planning process, and the advancement of a new pre-flight briefing tool – delivering the right information to Flight Crew at the right time and in the right format.

Task Problems

Across the first four studies, there was much convergence in terms of the identification of task problems. For purposes of analysis, these have been grouped into three overall types: (1) process, (2) tools and information and (3) crew factors/human factors. A summary of these problems is presented in Table 33 below.

It should be noted that there is a relationship between these different sets of problems. Critically, process design problems have led to certain problems with the HCI design of existing tools. This is discussed in more detail in a later section.

Table 33: Task Problems Associated with FC Execution of the Pre-Flight, Flight Planning and Briefing Task (Discussion)

Category	#	Problem	Source (Study)
Process Design	1	Flight Crew inherit problems arising from decisions made in Flight Planning process (e.g. crew composition, roster schedule and specification of flight plan)	Study 1 and 2
	2	Managing complexity of operation (e.g. aircraft changes, crew changes and route changes) – necessitating re-briefing and flight plan changes	Study 1, 2 and 4
	3	Weak feedback from safety to (1) Flight Planning and to (2) Flight Crew	Study 1, 3:1 and 4
	4	Weak information sharing across different actors involved in the Active Flight Operations process	Study 1, 2 and 4
	5	Reduced turnaround times/little time available for briefing	Study 1 and 4
Tools/Information	6	No summary overview of flight information	Study 4
	7	Lack of detail relating to certain flight plan parameters (e.g. fuel, technical status and crew information)	Study 4
	8	Existing cockpit tools do not provide support for crew CRM activities	Study 3:3 and 4
	9	Lack of information updates (i.e. real time picture as situation evolves)	Study 4
	10	Lack of flight specific risk information	Study 1, 3:1 and 4
Crew/human factors	11	Crew complacency in relation to the requirement to brief	Study 1 and 4
	12	Procedural drift	Study 1, 3:3 and 4
	13	Crew attitudes to CRM/briefing	Study 1, 3:3 and 4

Origins of these task Problems

Process design

The first four studies provide considerable evidence of information flow problems both at an operational and organisational level, arising from the design of the existing Flight Operations process, which have an impact on Flight Crew performance of this task. The process design dictates how information is shared between Flight Crew and other team agents. Further, it determines what information is communicated to Flight Crew in terms of the design of the Flight Plan. The five process mapping workshops highlighted several process design problems related to sharing of operational information between team agents. Through the course of the workshops, it became apparent that the procedures for sharing information between Flight Crew and the broader team are not well defined. Often, key operational information is not 'pushed' to Flight Crew. As a result, the crew engage in many informal information gathering activities, in order to 'pull' this information from relevant team agents. Critically, these informal co-ordination activities are not defined in existing SOPs. Further, the process workshops identified many weaknesses in relation to the communication of safety analysis feedback to relevant operational functions. This includes Flight Planning (i.e. Aircraft Pairing and Rostering, Dispatch and Flight Operations Control) and Flight Crew.

The findings of Study 2 and Study 3: 1, suggest that improved processes are required in relation to the communication of safety feedback to relevant Flight Planning functions. Further, the findings of Study 4 appear to validate the findings of Study 1 in relation to the identification of weaknesses in existing process design pertaining to the sharing of both operational and safety information between different flight operations functions and Flight Crew. Moreover, feedback from Safety personnel as part of Study 3: 1 indicates that there is room for improvement in relation to the provision of safety feedback to Flight Crew.

In addition, the finding of Study 1 and 4 indicate that the design of the process determines the time available to crew to perform the task. As shown, the introduction of low cost business models has created a requirement for a reduction in turnaround times. As indicated in Study 1 and 4, this has resulted in less time for briefing, which impacts negatively on Flight Crew briefing activities. This is in line with the strategic agenda of the airline. However, it is not in line with the requirements for a good briefing, as reported by Flight Crew.

Thus, following from McDonald's analysis (2005; 2006), these process design problems can be conceptualized as constraining Flight Crew task performance. This therefore sets the agenda for process redesign requirements to support the delivery of the right information to Flight Crew, by means of an improved Flight Plan.

HCI: Tools/Information

The design of the process has an impact on what information is communicated to Flight Crew in the Flight Plan. Thus, issues with regard to lack of flight specific risk information arise given the design of the existing process. Nonetheless, certain HCI design problems can be attributed to a mix of both process design issues and specific HCI issues concerning the particular medium used. As shown, it is not possible to deliver real time updates to Flight Crew in the flight plan if the medium used is paper. However, this does not preclude the efficient delivery of this information to Flight Crew using an alternative format. Airlines 1, 4 and 5 use a paper Flight Plan. Communication updates are delivered to Flight Crew either in person via the Co-ordinator, or indirectly, using the crew members mobile phone or ACARS. As shown in research with Airline 2 and 3, although the crew brief for the flight using an electronic Flight Plan (i.e. use of computer in crew room to brief on flight), operational updates are not provided in the Flight Plan. Rather, updates are communicated in the same manner as the other airlines. In all cases, these communication methods cause problems for Flight Crew. Thus, both the process and the Flight Plan must be designed to facilitate improved communication mechanisms.

Crew Factors, Safety Culture and Crew Resource Management Training

Lastly, problems related to the disposition of the crew to make a full and complete briefing and issues related to procedural drift (Helmreich, 1999a) were noted. Here, individual differences must be considered. Also, as highlighted in Study 3: 2, these can depend on the particular flight situation (i.e. level of complexity). Further, as reported by Flight Crew participants in Study 1 and Study 4, this can vary according to the crew composition. Nonetheless, these problems can be analysed in relation to the prevailing safety culture. Here we must consider the professionalism of Pilots and the pervasive safety culture at a particular airline. As highlighted in Study 3:3, it is essential that the airline's CRM training emphasizes the importance of briefing both from an operational and safety perspective. Also, CRM training must clearly communicate the requirements for a good briefing. Further, airlines should promote and potentially reward 'high involvement' crews who actively manage flight safety issues at different points in the process. This is discussed in more detail in a later section in relation to the Intelligent Flight Plan concept.

Conceptualizing and Resolving Task Problems

Across the six studies, there was much convergence in terms of identifying how Flight Crew task problems pertaining to the performance of the pre-flight, flight planning and briefing task, might be resolved. As shown, these problems are within the control of the airline to resolve. By changing the process and specifically, changing what information is communicated to Flight Crew in terms of a new Flight Plan, it is possible to change the way

the task is performed. Thus, the delivery of information, by means of the specification of improved flight operations processes and tools, provides the mechanism in which to resolve these task problems.

Therefore, the task problem can be posed both from a process design and HCI perspective. In line with McDonald's analysis (2005; 2006), we must pose the question of how the process should be redesigned to ameliorate Flight Crew task problems at the pre-flight stage. Following from this, the HCI question can be posed. That is, what is the remit of new tools in terms of resolving these process design problems? In particular, what are the requirements for a new electronic Flight Plan in terms of resolving Flight Crew task problems related to the sharing of operational and safety information at the pre-flight stage?

As shown, the process must deliver the right information to Flight Crew in a timely manner to support task performance. As highlighted in Study 6, this is underpinned by specific process rules in relation to the communication of safety feedback to Flight Planning to ensure intelligent planning and better real time management of flight threats (i.e. by Dispatch and Flight Operations Control). This in turn assists Flight Crew task performance. Also, there is a requirement for improved flight planning activities, to ensure that potential flight threats are managed earlier in the process (i.e. crew composition and routing) and to reduce the levels of complexity encountered by Flight Crew. Moreover, there is a requirement to improve the provision of safety feedback to Flight Crew. In particular, flight specific risk guidance must be provided to Flight Crew, following from the reactive and proactive risk assessments conducted by Safety personnel.

These process requirements form the basis of the specification of new tool requirements supporting Flight Crew performance of the pre-flight, flight planning and briefing task. Such a tool should provide the appropriate level of task information to Flight Crew, at the right time and in the right format. In addition, this tool should provide task support for specific briefing and TEM functions, so as to enhance teamwork and promote joint situation assessment. As highlighted in Study 3: 2, the enhanced briefing package provided by the dispatch department of Airline 2 to crews flying the Alta approach, goes some way towards this solution. Further, as demonstrated in Study 3:3, the new briefing checklist and TEM template developed by Airline 5, also facilitates some of these requirements. However, these tools do not go far enough. Overall, a new tool is required. Thus, the proposed Intelligent Flight Plan is designed to bridge this gap.

5. REQUIREMENTS FOR A GOOD BRIEFING

Introduction

As stated previously, the first four studies suggest certain task problems related to Flight Crew execution of the pre-flight, flight planning and briefing task. Collaborative prototyping and evaluation activities undertaken as part of studies 5 and 6 facilitated the envisionment of a future task which attempts to resolve these problems. Critically, the specification of an improved task (or future task) which emerged in this research demonstrates the characteristics/requirements of a good briefing. These requirements have been grouped into six related categories. This includes: (1) task functions, (2) procedures, (3) tools and information (4) process design, (5) human factors/social process and (6) training. Overall, the analysis of these characteristics follows from a number of arguments made previously in relation to: (1) the key operational and safety outputs of this task, (2) the role of information and tools in supporting task performance, and (3) the shaping influence of the process in terms of governing what information is shared across different team agents and tools at different points in the Flight Operations process timeline, and specifically, at the pre-flight stage. Further, these requirements (and in particular the specific human factors requirements) follow from a consideration of CRM theory (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b).

Requirements for a Good Briefing

Task Functions

A good briefing achieves several related task functions. This includes: the establishment of the team concept, the assignment of flight roles, the assessment of the risk status of the operation (including the addition of threats information not recorded in the system), the review of all relevant flight information (i.e. routing, weather, crew, aircraft technical status, fuel, load and NOTAMS), the confirmation of the fuel figure and/or request for additional fuel, the approval of the recommended routing (i.e. route, flight levels and alternates) and/or recommendation of changes to the routing, and the signoff of the Flight Plan.

Procedures

Clearly defined procedures are a prerequisite for a good briefing. The role of both the Captain and the First Officer in relation to the performance of the briefing task must be clearly defined. This includes the procedure for initiating the briefing, the level of teamwork required and the nature and scope of decision making. The particular process for analysing

flight threats and identifying threat management strategies must be defined. Procedures must make clear the criteria for requesting extra fuel and the process for this. Flight Crew collaboration requirements with other agents must be specified. Operational changes and information updates must be communicated in a timely fashion to crew, so that they have the opportunity to review these changes and conduct a re-briefing if required. In addition, the requirements for conferring with the Dispatcher and/or Flight Operations Control must be clearly established. Lastly, the criteria for a go/no go decision linked to the risk status of the flight must be transparent.

Tools & Information (Flight Crew)

The quality of tools and information available to Flight Crew, underpin this task. As highlighted in Study 1 and Study 4, all relevant information must be to hand. The findings of studies 4, 5 and 6 indicate that the scope of this information includes the following: the risk status of the flight, detailed information about flight risks, information about flight plan changes/updates, additional briefing information, the fuel figure composition and the justification for this, weather information, routing and alternates, crew information (fleet experience and route experience), aircraft technical status information and NOTAMS information. In relation to additional briefings information, this includes the following: typical CRM briefing required, special departure/approach procedures, and aircraft operating characteristics and tips.

This information must easily accessible and presented in an intuitive format. Flight Crew must have the latest information about operational updates/changes. A summary overview of the key Flight Plan information must also be provided.

Process

The process must be designed to allow for the communication of the right information to Flight Crew at the right time. This requires the specification of relevant safety feedback loops to (1) Flight Planning to support an intelligent flight planning process and to (2) Flight Crew, to facilitate relevant briefing task functions. Flight Crew must have sufficient time to perform a comprehensive review of all flight information and to make any decisions relating to ATC/routing changes. If last minute changes are required, there must be sufficient time available to re-brief on these. Also, in line with the research of Stewart (2006) and Stewart and Abboud (2005a; 2005b), crew rosters should be designed to ensure that crew members are not fatigued.

Human Factors/Social Process

In keeping with CRM frameworks (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b), and the social process frameworks advanced by McDonald (2005;

2006) and Morrison (2007; 2009), teamwork underpins a successful briefing. As highlighted in studies 1, 2, 3:1, 3:2, 3:3 and 4, this teamwork spans the local team (i.e. between Flight Crew), and the more global team (i.e. between Flight Crew and other Flight Operations functions such as Safety, Flight Operations Control/Duty Manager, Flight Planning, Dispatch, Maintenance, Cabin Crew and Ground Handling).

Further, both crew members must be disposed to CRM concepts in terms of appreciating the benefits of making a complete briefing. Also, both crew members must be motivated to make a complete briefing at the pre-flight stage.

Training

As highlighted in Study 3:3, Flight Crew must have received adequate training in relation to understaning the key role of the briefing task in terms of delivering on both operational and safety objectives. Further, both crew members should understand the requirements for a good briefing. As such, the specific implications of CRM theory in relation to the execution of the pre-flight, flight planning and briefing task should be explicitly communicated to Flight Crew in CRM training sessions.

6. PROPOSED INTELLIGENT FLIGHT PLAN CONCEPT

Proposed Intelligent Flight Plan (IFP) Concept

Objective

The overall objective of the Intelligent Flight Plan (IFP) is to support the requirements for a good briefing. Specifically, the objective is to improve the quality of Flight Crew pre-flight, flight planning and briefing activities, and where possible to solve the process and task problems associated with this task as outlined previously. Primarily, this concerns Flight Operations process problems pertaining to the sharing of both operational and safety information across the wider socio-technical system, which impinge on Flight Crew performance of this task.

Overall Intelligent Flight Plan (IFP) Concept

The proposed Intelligent Flight Plan concept is predicated on an understanding of the role of the briefing task in relation to the broader Flight Crew task. Specifically, the IFP concept delivers on the requirements for a good briefing following from CRM principles (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b). Three versions of the proposed Flight Plan are provided (i.e. current flight, next flight and future flights). This links to the different briefing contexts as outlined in Study 4. The proposed IFP is accessible using

different applications. This facilitates user access in different task environments as defined in Study 5. The Personal application allows crew to brief for future flights from a remote location (i.e. home or hotel). The Dispatch application is used for briefing for the current flight only – in the crew room. Lastly, the EFB application supports briefing for both the current flight and the next flight, from the cockpit.

IFP (Current Flight)

In relation to the IFP for the current flight only, a number of core tools features have been identified. These are summarised in Table 34 below.

Table 34: Core Flight Plan Features (Discussion)

#	Flight Plan Feature
1	The Flight Plan is embedded in the flight operations process.
2	The Flight Plan provides crew with all relevant task support information.
3	The Flight Plan provides electronic access to all relevant task information – both from the cockpit (e.g. EFB application) and from the dispatch room (e.g. Dispatch application).
4	Information is pushed to Flight Crew.
5	The Flight Plan facilitates an at a glance analysis of the flight situation.
6	The Flight Plan allows crew to actively partake in the pre-flight, flight planning and briefing task.
7	The Flight Plan actively supports crew application of CRM and TEM concepts in the operation.
8	The Flight Plan allows crew to perform a number of high involvement tasks on an optional basis.

New tools/technologies should not be introduced merely on the basis that the technology is available. Rather, new technologies should be introduced to solve real world task problems linking to the operational and organisational situation in which Pilots perform their tasks. To this end, the proposed IFP is embedded in the Flight Operations process. As such, the IFP (1) facilitates information sharing across the different operational agents involved in the flight operation, and (2) exploits the outputs of airline safety analysis.

The IFP integrates information across the different operational agents involved in the flight operation. This includes information from Dispatch (i.e. fuel composition and the reason for adding additional fuel, and gate information), Maintenance information (i.e. the technical status of aircraft and information about deferred defects) and information from the Boarding Agent (i.e. latest information about passengers). This assists crew in terms of the development of an operational based situation picture. Moreover, this fosters team work across all agents involved in the operation. Further, it ensures that crew don't waste valuable

time looking for information. This is important given the limited time available for the pre-flight, flight planning and briefing task, as reported in Studies 1 and 4.

Following from the recommendations of different stakeholders across the first four studies, the proposed IFP exploits the output of airline SMS analyses. Specifically, the IFP provides the crew with risk/threats information customised for their particular flight. This includes an overall assessment of the risk status of the flight, an specific assessment of flight threats in relation to three threat categories (i.e. crew, aircraft and environment), and detailed information about particular flight threats identified. Best practice information in relation to the management of potential threats and error avoidance is also provided.

Overall, the main focus of the IFP is to solve problems related to provision of information to Flight Crew. In this way, the design of the IFP follows from some of the information theory/HCI theory concepts outlined in the Introduction. Specifically, the IFP attempts to provide the crew with information as opposed to raw data. Further, it attempts to provide sufficient information and thus avoid information overload situations. Also, it endeavours to provide this information in a format that is easily accessible and easy to assimilate.

So what information is provided? This includes information already provided in existing flight plans (i.e. weather, fuel, NOTAMS, routing and airport information), and new information (i.e. information about flight threats, briefing guidance, operational updates/changes information, crew information, passenger status information, maintenance status information, gate information and fuel trends information). Further, the Flight Plan provides access to additional documentation in electronic format. This includes access to CRM briefings, special approach briefings for certain airports, charts and SOPs. Crew can assess this information, both from the dispatch room (i.e. using the Dispatch application) and from the cockpit (i.e. using the EFB application). The provision of the right information to crew ensures that flight plan decisions are made in the light of the most up to date information. As such, crew are not forced to rely on intuitive judgement. It is anticipated that the provision of this additional information will enhance the quality of Flight Crew briefing activities.

Evidently, the information provided must be of a good quality. As evidenced in studies 1 and 4, the quality of information can be characterized in terms of its task relevance, accuracy, completeness (e.g. level of detail) and clarity.

Nonetheless, the provision of task support information on its own is insufficient. This information must be easily accessible. As shown, the IFP is available in different formats, to facilitate quick access in different contexts. Specifically, the Flight Plan for the current flight is available on the Dispatch and EFB applications only.

Also, as highlighted in studies 1, 4, 5 and 6, this information must be delivered in a timely manner. The flight plan pushes key information to Flight Crew. The timely provision of key

information to Flight Crew ensures that Flight Crew stay focussed on the assessment and use of information. As such, valuable time is not wasted on gathering data.

Following FAA guidance (1996) in relation to providing support for situation awareness and situation assessment, a dashboard is provided which provides a summary overview of the risk status of the flight, and key flight information. This assists the rapid advancement of a preliminary situation picture. Again, this is critical, given the limited time assigned to crew briefing activities.

The new design allows crews to actively partake in flight planning tasks. Flight Crew can request additional fuel and deal directly with the Fuel Agent. The design allows Flight Crew to change alternates, in collaboration with the Dispatcher and the Duty Manager. Further, Flight Crew can request information updates and signoff the Flight Plan. In this way, the crew are more actively involved in flight planning process, specifically in relation to the co-ordination and actioning of collaborative tasks.

The introduction of new technology affords the opportunity to challenge preconceptions as to what aspects of the task technology can assist. As shown, technology development is not simply about extending existing tool concepts. Rather, technology development requires innovation in relation to a consideration of how technology might support certain tasks not previously assisted. Specifically, this includes providing technology support for key non technical tasks. This overall approach is previously exemplified in the research of Funk (1996; 1999), in regard to the advancement of new task management tools. As highlighted in studies 1, 2, 3:3 and 4, the quality of crew CRM/TEM activities has an impact on the safety and operational outcome of the flight. Thus, the provision of task support for crew CRM/TEM activities should be considered. The IFP can be conceived as a vehicle for this. Specifically, the IFP externalizes these socio-cognitive activities. With the exception of the tool innovations advanced by Airline 5, the link between crew training concepts (i.e. CRM and TEM concepts) and the design of task support tools, has received minimal attention.

In an effort to tackle issues related to crew complacency as to the requirement to brief, along with more general trends related to procedural drift, the IFP prompts users about the requirement to brief. In addition, the IFP provides crew with relevant briefing information. This includes relevant information about specific flight/operational threats and associated briefing guidance. This builds on existing research advanced by Airline 5 in relation to the development of a pre-flight briefing checklist. This purpose here is to build briefing into the task, and to assist crew development of a shared situation model.

The assessment of the risk status of the flight (and associated dispatch status) is classified in terms of three risk levels – low, medium and high. In principle, these risk levels correspond to the different ways in which the crews characterize a flight situation (i.e. good, bad, and 'in between'), as outlined in Study 4. Specific threats are grouped into three different threat

categories - crew, aircraft and environment. These threat categories correspond to the taxonomy of threat types as posed by Flight Crew representatives from Airline 5, in Study 4. Crew can view risk information for the specific flight, according to the process phase, sub-phase and process gate. This information is time stamped in the sense that the TEM information is the latest information that is available in the system, at the time the Dispatcher publishes the final flight plan (i.e. one to two hours before the flight commences). In addition, the proposed Flight Plan updates crew with information concerning any new threats identified in real time (i.e. threats identified in real-time by Dispatcher, Flight Operations Control, and/or other Flight Crew). This is communicated to Flight Crew in the operational updates and messages section. Further, any updates relating to operational changes or issues (i.e. gate changes, crew changes and aircraft changes) are communicated in the latest operational updates and messages section. It should be noted that some of these operational updates/messages may be actual threats (i.e. update about bird-strike as reported by other crew members landing at the given airport), or have the potential to become threats (i.e. aircraft change which results in crew rushing a departure briefing to keep the ATC window). Further, crew can view best practice information about how to manage threats (i.e. guidance derived from operational reports/TEM information provided by crew and training guidelines).

A number of high involvement options are also provided to crew on an optional basis. Firstly, Flight Crew can add additional information about how they plan to manage existing threats. Flight Crew can also input information about threats not already recorded in the system, and how they propose to manage them. The crew can also add information about a specific flight or more general guidance/tips to be shared with other operational personnel. Lastly, Flight Crew can send aspects of the briefing to the Senior Cabin Crew to foster an overall team concept and common situation view. Overall this ensures that Flight Crew and Cabin Crew have a common understanding of the flight situation. As highlighted in study 1 and 4, if the Cabin Crew are briefed about the constraints facing Flight Crew, then they are in a better position to identify how best to support the performance requirements of both the Flight Crew and the broader process.

IFP & Solving Task problems

Studies 1 and 4 identified several task barriers pertaining to the execution of the pre-flight, flight planning and briefing task. Further, these studies have identified certain more general problems related to the design of procedures and procedural drift. Overall, it is anticipated that the introduction of a new electronic flight plan tool, might solve and/or mitigate some of these problems.

So what problems can the new IFP solve? It is anticipated that the introduction of the IFP will solve several problems related to information access and availability. In the current process,

information pertaining to operational updates/changes is not pushed to Flight Crew. Rather, the crew must gather information from different operational roles in an opportunistic manner. This process is often piecemeal, often resulting in delays. To this end, the IFP provides latest updates relating to the flight. Moreover, the messages section supports ongoing information sharing between relevant operational agents. As reported in studies 1, 3:1 and 4, the briefing package is not linked to airline SMS activities. As such, the Flight Plan does not provide instruction in relation to flight threats. The proposed IFP is integrated with the broader SMS process, and provides detailed information in relation to flight threats. Participants also reported a lack of detail in relation to certain information. Accordingly, the IFP provides more detailed information in relation to the fuel figure, the crew and the technical status of the aircraft. The first four studies also highlight certain more general problems related to procedures, both at a Flight Crew level (i.e. procedural drift, complacency and indeterminacy in relation to certain flight contexts) and in terms of the design of broader Flight Operations processes (i.e. poor information sharing both within and across flight operations processes). Potentially, the IFP can be used to help resolve some of these problems.

However, the introduction of the IFP will not solve all problems. It is not likely that turnaround times will be extended in the current low cost environment. Nonetheless, it is possible to tackle this problem from a HCI/information flow perspective. In this respect, the problem becomes one of identifying what information should be provided to crew to support a fast collaborative assessment of the flight situation. The flipside of this is minimising unnecessary time wasting in relation to the gathering of relevant flight situation data. As shown, the IFP provides the latest operational updates information to Flight Crew. Further, the first screen of the IFP provides an 'at a glance' summary of salient flight information, supporting a quick assessment of the flight situation. Depending on the flight situation, the crew may then decide to spend more or less time analysing particular crew factors. Thus, although the IFP concept may speed up the briefing and analysis of flight threats, a dedicated briefing is still necessary.

Problems related to crew complacency in terms of the requirement for a detailed briefing were reported. Also, studies 1 and 4 indicated that the specific crew composition may or may not be conducive towards making a briefing. On it own, the IFP will not change crew attitudes to briefing. However, it can support the procedure. It is anticipated that the provision of detailed flight information configured in the TEM structure will focus the crew's attention on the requirement to brief. In other words, it will act as prompting device. Nonetheless, the crew need to value briefing and have an interest in using the TEM aspects of the IFP.

Also, the IFP may not solve certain more general problems identified in this research. The IFP will not change the level of complexity associated with Flight Operations. Further, it will not solve other issues associated with lost cost operations (i.e. fatigue given long working

days). That said - the IFP may indirectly support the management of these issues, in terms of providing task support for TEM activities.

As highlighted in Study 6, the IFP is not a stand alone concept. The IFP is only possible if appropriate operational/safety data can be gathered about the operation, linking to broader proactive and reactive risk assessments activities. Critical to this, is the generation of routine reports by frontline personnel and especially by Pilots. As outlined in studies 1 and 3:1, currently there are many barriers to routine/voluntary reporting. Thus, the successful introduction of the IFP depends on resolving these problems. As suggested in Study 1 and Study 3:1, this may require the parallel introduction of new reporting formats, the provision of feedback concerning the status of reports to Flight Crew, and enhanced communication between Safety and Flight Crew concerning the nature of the SMS process and the role of reporting.

Conclusions

1. CHAPTER INTRODUCTION

This chapter presents the overall conclusions of this thesis. First, thesis conclusions in relation to the emerging task models, the analysis of the thesis problem and it resolution, the HCI requirements for a new tool supporting Flight Crew performance of the pre-flight, flight planning and briefing task and the allied process redesign requirements necessary to the implementation of this tool concept are stated. The contribution of this thesis to new knowledge is then reviewed. Following this, areas for further analysis are outlined. Lastly, the practical implications of this research are presented.

2. OVERALL THESIS CONCLUSIONS

Flight Crew Task Models

The Flight Crew task involves more than flying the aircraft and interacting with different human agents and tools, in accordance with standard operating procedures (SOPs). Rather, the Flight Crew task involves managing different levels of complexity associated with the physical flight environment, the team environment and the broader operational and organisational system. In so doing, the Flight Crew act as a co-ordinating interface between different human agents involved in the Active Flight Operations process and other processes that interface with this process. Central to this is the management of information. Flight Crew obtain relevant task support information from different team agents and tools. Specifically, information is used to assess the situation and identify an appropriate course of action. Critically, the quality of tools and information available to Flight Crew both shapes task performance and impinges on task outcomes. However, the nature of the information provided to crew – both in terms of the human computer interaction (HCI) design of task support tools and the information provided by team agents – is determined by the underlying process design.

The pre-flight, flight planning and briefing task plays a key role in terms of Flight Crew management of complexity and the associated co-ordination of information inputs across different team agents and tools. The pre-flight, flight planning and briefing task is also essential in terms of cementing team concepts, supporting team situation awareness and managing workload. Further, this task is important from an operational perspective. The signoff of the Flight Plan is a key step in the operational process. Moreover, this task

functions as a key interface between the management of the process by Flight Crew and the wider management of the process by Flight Operations Control.

Several problems related to the execution of the pre-flight, flight planning and briefing task can be identified. Primarily, this concerns weaknesses in relation to the delivery of relevant operational and safety information to Flight Crew in the existing Flight Plan, weaknesses in the sharing of information between Flight Crew and other agents at the pre-flight stage and more global weakness in the sharing of safety information across different Flight Operations functions at different points in the Flight Operations process timeline. Also, following from Crew Resource Management (CRM) theory (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b), there is a notion of good practice in briefing. Yet, Flight Crew briefings at the pre-flight stage often fall short of this. Further, Pilots can be complacent about the importance of applying CRM principles. In addition, the introduction of low cost business models has led to reductions in turnaround times. As a result, Pilots have less time to perform this task.

Analysis of Thesis Problem & How it Can be Resolved

The thesis problem and its resolution can be conceptualized both from a HCI and a process design perspective. Specifically, the thesis problem concerns both the HCI design of the existing Flight Plan (and in particular, the information provided to Flight Crew in the Flight Plan), along with the process design rules inherent in the sharing of operational and safety information across team agents and tools, at different points in the process to support the individual and collaborative task requirements of the process.

Critically, the delivery of the right information to Flight Crew by means of an improved Flight Plan, and the parallel specification of improved Flight Operations processes assisting information flow across team agents at different points in the overall Flight Operations process timeline - provides the mechanism in which to resolve Flight Crew task problems at the pre-flight stage. That is, by changing the process and specifically, changing what information is communicated to Flight Crew in the Flight Plan, it is possible to transform the way the task is performed for the better. Thus, the introduction of an enhanced Flight Plan provides the task and information support necessary to facilitate a more powerful briefing (i.e. good practice in briefing).

Intelligent Flight Plan Concept & Process Redesign Requirements

New tools are required to facilitate the communication of enhanced task support information to Flight Crew. Specifically, this includes the provision of detailed Flight Plan information (i.e. routing, weather, fuel, load, aircraft technical status, crew and NOTAMS), operational updates information, information about the risk status of the flight, and information to support crew TEM activities.

Further and in support of this, new processes are required to support the delivery of the right information to Flight Crew at the pre-flight stage. Improved processes in relation to the sharing of operational information across relevant team agents involved in the Active Flight Operations process are required. Also, improved safety management processes are required to support the management and communication of safety analysis information to Flight Planning personnel, to facilitate an improved 'intelligent planning' process.

Most of the research conducted in this thesis is Flight Crew centric. The requirement for process redesign changes and specifically an improved Flight Plan came out of a need articulated by Flight Crew participants both in the process workshops as part of Study 1, and in the more detailed task analysis undertaken with Flight Crew participants from Airline 2 and Airline 5, in Study 4. The evidence for this is less strong in relation to the analysis of both Safety and Flight Planning processes. As remarked in both Study 2 and Study 3:1, less detailed research was conducted with Flight Planning and Safety representatives, both in relation to understanding their perspectives on these issues, and assessing the requirements to change/improve their respective processes. Nonetheless, Study 3 and Study 3:1 provide some evidence to support this requirement. As stated above, these studies highlight process design weaknesses in relation to the communication of safety feedback to wider Flight Operations functions. As emphasized in Study 3:1, additional research is required to map in more detail the existing safety management communication processes and the specific challenges faced by Safety personnel in terms of providing adequate feedback to relevant Flight Operations functions. Moreover, as highlighted in Study 2, additional research might be conducted with Flight Planning, to understand their specific feedback requirements, and how this information might be put to best use in the Flight Planning process. However, the requirement to improve existing safety management processes in terms of the provision of feedback to relevant Flight Operations functions follows from the SMS principles defined by ICAO (2006; 2009). In this way, these SMS principles lend support to the process redesign suggestions and the emerging Intelligent Flight Plan concept proposed in this research. Further, these improved information sharing processes support the advancement of a 'high reliability organisation' as defined by Weick and Roberts (1993). Moreover, it is anticipated

that these new processes will go some way towards mitigating 'information disasters' as defined by Turner and Pidgeon (1997).

Arguably, the test of any concept (i.e. new process and/or new technology concept) is whether it can be easily implemented. At the moment, this is more an aspiration than a reality. Further research is required in relation to specifying and assessing the operational and organisational processes, along with the technology integration requirements, supporting the implementation of this concept at the airline.

3. CONTRIBUTION TO NEW KNOWLEDGE

This thesis has resulted in several contributions to new knowledge.

HCI Methodology

First, a new HCI methodology is proposed. As shown, this methodology facilitates the envisionment, design and evaluation of new HCI tool concepts in the context of the broader operational and organisational system, in which the proposed tool will be used. This methodology meets several core theoretical requirements in relation to the specification of a valid task model and the design of the future system, as emerged in the analysis of both socio-technical systems theory and HCI theory. Overall, this methodology involves the integration of both formal and informal HCI methods, along with process mapping methods used in the Organisational Ergonomics field.

Flight Crew Task Model

A new integrated model of Flight Crew task performance is provided. This involves a descriptive account of Flight Crew task activity at different levels. This includes: (1) a model of task performance in terms of key socio-technical elements and their relationships, (2) a model of task performance in relation to different levels of process, (3) a model of task performance in relation to duty status, and (4) a model of Flight Crew role/task functions. Taken collectively, these different levels of task model yield an integrated account of Flight Crew task performance. Arguably this 'joined up' account resolves certain problems with existing task models – specifically, in relation to an understanding of the shaping influence of the process on the Flight Crew task, the impact of team task performance requirements on Flight Crew task activity, and the role of tools and information in shaping Flight Crew task performance.

Model of the Pre-Flight, Flight Planning and Briefing Task

This thesis supplements existing descriptions of the pre-flight, flight planning and briefing task, as provided in airline SOPs. Overall, this task is conceptualized from a socio-technical perspective. In so doing, this account highlights the shaping influence of the process on task activity, teamwork requirements and the impact of team activities on the task, the role of context, and the influence of tools and information on Flight Crew task activity. The human factors dimensions of this task are also explained. Further, the nature of Flight Crew TEM activity is described.

Requirements for a Good Briefing & Future Briefing Task

This thesis provides an account of the requirements for a good briefing. Critically, these briefing characteristics reflect a future and/or improved task. Specifically, the requirements for a good briefing are defined in relation to six high level categories. This includes: (1) task functions, (2) procedures, (3) tools and information (4) process design, (5) human factors/social process and (6) training. The analysis of these characteristics follows from a number of thesis arguments concerning: (1) the key operational and safety outputs of this task, (2) the role of information and tools in supporting task performance, and (3) the shaping influence of the process in terms of governing what information is shared across different team agents and tools at different points in the Flight Operations process timeline (and specifically, at the pre-flight stage), to support the performance requirements of this task. Further, these requirements (and in particular the specific human factors requirements) follow from a consideration of CRM theory (Cooper, White & Lauber, 1980; Helmreich, 1999a, 1999b; Helmreich and Foushee, 1993; Helmreich, & Merritt, 2000; Johnston, 1993, 1994; Wiener, 1983, 1985a, 1985b).

Intelligent Flight Plan Concept & Underlying Process Requirements

This thesis has resulted in the specification of a new Flight Crew tool concept – the Intelligent Flight Plan. The proposed tool concept is predicated on an understanding of the role of the pre-flight, flight planning and briefing task in relation to the broader Flight Crew task. Critically, the proposed tool concept addresses the specific problems identified in this research in relation to Flight Crew execution of this task, along with the underlying process design issues that contribute to these task problems. In so doing, it endeavours to deliver on the requirements for a quality briefing. Further, this thesis provides a preliminary account of the underlying Flight Operations processes necessary to the implementation of the Intelligent

Flight Plan concept at the airline. In particular, this includes new safety/risk management processes and allied intelligent planning processes.

4. AREAS FOR FURTHER ANALYSIS

Process Maps & Flight Crew Task Model

Process mapping of the Active Flight Operations process took the perspective of the Flight Crew role. Although other role contributions were considered, these were not explored in great detail. Additional research might focus on advancing the same process map from the perspective of other roles (i.e. ATC, Maintenance, Cabin Crew, Co-ordinator, Dispatch and Flight Operations Control). Following this, the emerging process maps might be integrated so that one overall is produced. Process mapping of the planning process and the Safety/Quality/Improvement process was high level and concentrated mostly on the inputs and outputs to Flight Crew. A more complete picture of both processes is required.

In addition to process mapping, a detailed task analysis might be undertaken in relation to ATC, Dispatch, Flight Operations Control and Maintenance. This would ensure that the proposed model of Flight Crew task performance takes into account the performance constraints of these other roles.

The numbers of participants available for interviews and the time allotted to individual interviews was restricted given airline operational constraints (e.g. requirement to release personnel from the operation). Most of the Pilots flew short haul. Only a small group of Pilots flew long haul. Supplementary task analysis might be conducted with other long haul Pilots, specifically focusing on general task themes (i.e. relationship between task and process, team dimensions and issues related to managing operational and environmental complexity) and the specific pre-flight, flight planning and briefing task. The Pilots recruited for these studies also reflect a spread of operational experience with a range of European airlines. To avoid cultural biases, a further study, might validate these task models with Pilots from other regions (i.e. America, South America, Africa and Asia).

Intelligent Flight Plan (Current Flight)

HCI Concept

Certain aspects of the HCI execution require additional research. The relay of flight specific TEM information and associated best practice tips for managing threats requires elucidation. In addition, the workings of the operational updates/messages section requires further analysis. It is necessary to understand what information will be relayed to crew in the form of

electronic messages, and what information will be relayed either in person or using VHF radio. Further, the recording of this information must be considered.

The proposed HCI tool concepts are both provisional and high level. Further participatory sessions might be required to complete the tool envisionment exercises. Pending further development and validation, these concepts might be evaluated more formally. This might involve user testing and/or evaluation in situ. In this respect, performance measures and qualitative feedback should be obtained. Nonetheless, formal user testing is not enough. Proposed tools must be rated usable from the perspective of actual work practices. For this reason, it is proposed that additional observations be carried out. If users have difficulties completing tasks in 'real life', further re-design will be required.

Underlying Process and Tool Requirements

The introduction of the proposed Intelligent Flight Plan necessitates the introduction of new processes/information sharing practices, across the range of agents involved in the three Flight Operations processes. Many processes have not been specified, and/or are only specified at a high level. Further, the specification of these processes has been mostly Pilot led. As such, the concepts advanced reflect certain Pilot biases. Critically, these processes require more detailed specification. This might be undertaken with a panel of participants reflecting the diverse processes/functions involved (i.e. Flight Crew, Safety, Flight Planning and Dispatch). This may result in changes to the existing Intelligent Flight Plan concept.

The generation of a flight specific risk rating, and associated risk information is beneficial from a Flight Crew safety/operations management perspective. However, the legal implications of this concept must be investigated. Underpinning this concept is the ongoing practice of safety/risk analyses. As part of this, the airline will generate a list of generic operational threats, and threats relevant to a particular flight. This information will be recorded in the airline's SMS system. If this information is communicated to Flight Crew in the form of the intelligent flight plan, what happens if a critical incident or accident emerges? What is the legal implication of this (i.e. responsibility of airline/of Flight Crew)? This must be determined.

The introduction of the proposed flight plan concept requires the development of additional technology for use by other agents. Particular issues related to the introduction of these tools (i.e. in terms of IT issues, process issues and specific work practice issues) were not explored. This might be examined in future research. This research may raise additional feasibility/implementation issues. Depending on the outcome, this may require changes to the proposed Intelligent Flight Plan concept.

Intelligent Flight Plan (Other)

Other Briefing Contexts

The Intelligent Flight Plan was developed in relation to three briefing contexts. This includes the current flight, other flights that day, and future flights (e.g. flights in the coming days). To date, research has mostly focussed on the advancement of the Intelligent Flight Plan for the current flight only. Thus the Intelligent Flight Plan concept for these two other briefing contexts requires more consideration.

Other Phase of Flight

Potentially, the Intelligent Flight Plan concept might be extended to assist intelligent planning and briefing for other flight phases. This is especially important in relation to the top of descent briefing and ongoing checklist briefings and informal briefings during the descent, approach and landing phase. Often, the situation picture can change at this point in the flight. This is true for both short and long range operations. As such, Flight Crew would benefit from enhanced information updates (i.e. weather, ATC restrictions, runway in use and status of airport landing equipment). Further, the provision of task support for collaborative decision making in relation to complex operations would be beneficial. This might take into account collaboration with all relevant flight operations agents (i.e. Duty Manager, Maintenance and Dispatch). This includes situations such as requests to divert following from poor weather conditions, CAT II/III approaches, landing with technical issues detected (i.e. one engine not running), and landing at sites that are not equipped for a precision approach.

Information Sharing With ATC

The proposed Intelligent Flight Plan concept suggest a potential way forward for (1) sharing operational information across relevant airline functions, and (2) managing the different levels of operational and organisational complexity associated with flight operations, linking to the existing flight operations concept. Potentially, this Intelligent Flight Plan concept might be further elaborated to include information sharing with ATC, in terms of the current operational concept.

Intelligent Flight Plan & New Operational Concepts

The introduction of new operational concepts such as free flight and reduced crew operations will change the nature of the Flight Crew task. In addition, this will impact on crew workload. Also, these changes will impact on the nature of the briefing task and allied task support requirements.

Future research might also address how the Intelligent Flight Plan concept might be advanced to follow the proposed assignment of ATC and Flight Crew functions, as outlined in the new Free Flight concept. In addition to changing both ATC and Flight Crew task practices, this would necessitate wider flight planning process re-design changes (i.e. implications for Dispatch and Flight Operations Control). Further, this would require information integration across wider stakeholders (i.e. Ground Operations, Flight Operations/Safety and Maintenance), above and beyond what is currently conceived in the Free Flight concept. This warrants further research.

Also, the Intelligent Flight Plan might be further elaborated to support the potential new configuration of cockpit roles as proposed by Harris (2007; 2009), in line with the implementation of the Free Flight concept. Specifically, the Intelligent Flight Plan might be extended to facilitate the new briefing processes inherent in the introduction of single crew concepts and/or changes to the configuration of cockpit roles.

5. PRACTICAL IMPLICATIONS OF RESEARCH

Process Design & Procedures

This research has implications for process design on a number of levels. This includes the flight operation level, the broader flight operations level and the ATC level. In relation to the flight operation level (i.e. design of Active Flight Operations process), it is argued that Flight Crew procedures (along with other role procedures) might specify team task performance requirements at different process gates and associated information sharing requirements. In addition, it is suggested that Flight Crew procedures might be described more generally, so as to permit Flight Crew optimisation of procedures in different contexts. In relation to the flight operations level, it is suggested that process re-design activities focus on improving information flow between Flight Crew, Dispatch and Flight Operations Control. Further, improved information sharing between Safety personnel, Flight Crew, Flight Planning and Flight Operations Control is proposed. Also, new SMS procedures are required, to support the gathering, integration, analysis and communication of relevant safety/operational information. Moreover, research indicates that information sharing processes between both Flight Operations and Maintenance might be improved. In terms of the ATC level, it is recommended that existing processes be redesigned to facilitate improved co-ordination between ATC and Flight Crew. Potentially, many of the problems reported by Flight Crew might be ameliorated by the introduction of new operational concepts such as Free Flight.

Performance/Safety Management Approach, Processes & Tools

This research has resulted in the definition of certain new performance management approaches and associated high level process and tool concepts, which might be exploited in terms of the specification of improved airline safety management processes and systems. Critically, research suggests several ways in which both operational and safety information might be used more intelligently within an airline.

CRM Training

It is proposed that CRM training make use of airline operational and safety information, as relayed in crew reports. Specifically, safety personnel might use this information to advance a series of safety studies premised on actual operational scenarios. During CRM training sessions, Pilots might review a specific operational scenario. In so doing, the threats faced by crew and how these were managed might be examined. Further, Pilots should be encouraged to evaluate the specific task management, communication, TEM and information management strategies utilized by crew. In addition, Pilots might be invited to evaluate whether SOPs could be followed in the given context and/or, whether they should have been optimised (and how).

CRM training provides an opportunity to cement team concepts. Potentially, the process maps advanced in this research might be presented in a visual format to crew, to encourage crews to think about team performance requirements at different process gates and associated co-ordination and communication strategies with different agents. Further, this map might be used to highlight the relationship between the Active Flight Operations process and other flight operations processes (i.e. Flight Planning and the Safety/Quality/Improvement process). Moreover, this map might be used to examine the links between Flight Operations processes and wider processes (i.e. Maintenance, Ground Handling and ATC processes).

As demonstrated, reporting is a critical Flight Crew task. Nonetheless, there are many barriers to reporting. Thus, CRM training must highlight the importance of reporting and where possible, mitigate these barriers. Specific reporting forms should be reviewed. Further, Pilots should be informed about how reports are used within the organisation (i.e. data protection and no blame culture) and associated airline performance management, risk management and organisational learning strategies. Potentially, this might motivate Pilots to report along with fostering an improved reporting culture.

CRM training also presents an opportunity for both safety and procedures personnel, to obtain feedback about the design of existing processes and potential process improvements.

Lastly, CRM training should emphasise the importance of crew briefing, at the pre-flight stage. Moreover, this training might be used to communicate the requirements for a good briefing, as specified in this research.

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