出國報告（出國類別：其他）

參加國際航空安全調查員協會 2011 年會報告

服務機關：行政院飛航安全委員會
姓名職稱：王興中／執行長
派赴國家：美國
出國期間：民國 100 年 9 月 10 日至 9 月 18 日
報告日期：民國 100 年 10 月 20 日

目錄

壹、前言

貳、會議議程

參、會議重點及心得摘要

肆、建議事項

伍、附錄

壹、前言

國際航空安全調查員協會（ International Society of Air Safety Investigators, ISASI）於 1964 年在美國創立，爲一國際航空安全調查之專業組織。其會員來自飛安及失事調查機關、民航主管機關、航空器、發動機及航電產品製造廠、航空公司、飛航安研究機構等。本屆年會有分別來自世界各地 33 國約 230 位代表參加。

本會自成立初期即加入該協會成爲正式會員，歷年皆派員參加該協會舉辦之年會，除籍由參加會議蒐集國際上飛航事故調查相關安全資訊外，亦和世界各國之事故調查機關建立聯絡管道，以做爲日後事故調查合作的基礎。

本會因執行科發計畫，於此次年會中和國防大學李文進博士共同發表 1 篇論文，「Pilots’ Cognitive Processes for Making In-flight Decision under Stress」，主要探討波音 B-747 駕駛員在不同情境下，如何使用 4 種決策下達的模式以獲取最適合的決策並解決問題，維護飛航安全。

貳、會議議程

本此次研討會由失事調查專業人士與學者專家進行多篇專題報告與研討，並舉行調查相關之專業訓練，議程如下：

Monday September 12

8：30 – 5：00 Digital Photography for Accident Site Investigation
Tony Gasbarro – Transportation Safety Board Canada
8：30 – 5：00 Improving Aircraft Integrity from Accident／Incident Analysis Information – Closing the Loop
Dr. David Hoeppner – University of Utah

Tuesday Sept. 13

8：30 Seminar Opening
Frank Del Gandio – President ISASI
Dick Stone – Chair ISASI 2011
8：40 Keynote Address
Marcus Costa
Chief, Accident Investigation Section - ICAO
9：00 Rudy Kapustin Scholarship Presentations
10：30 Impact Modeling – Cases and Cautions
Robert Carter - UK
Principal Inspector of Air Accidents - AAIB
11：00 Major Investigations, New Thinking Ahead
Bob MacIntosh - USA
Chief Advisor, International Safety Affairs NTSB
11：30 Questions／Discussion from the floor
1：30 Using "ASTERIX" in Accident Investigation
Michiel Schuurman – The Netherlands
Senior Investigator Aviation - Dutch Safety Board
Paul Farrell – Ireland
Inspector of Accidents - AAIU
2：00 Who Is Onboard in GA and Air Taxi Accidents?
Bob Matthews - USA
Office of Accident Investigation - FAA
2：30 Preventing the Loss of Control Accident

Patrick Veillette – USA
3：30 Analysis of Fuel Tank Fire and Explosion
N. Albert Moussa - USA
BlazeTech Corp.
4：00 Questions／Discussion from the floor
4：30 National Society Meetings

Wednesday Sept. 14

8：30 Teamwork in the Cause of Aviation Safety
Sébastien David - Léopold Sartorius - France
Safety Investigators – BEA
9：00 Long Distance Investigations
Thorkell Agustsson – Iceland
Chief Inspector, Air Accidents – AAIB
9：30 Smaller Nations & Annex 13
Syed Naseem Ahmed - Pakistan
Aviation Consultant
10：30 Timeliness, an Investigators Challenge
John Stoop – The Netherlands
Lund University, Sweden
Delft University of Technology, the Netherlands-
11：00 Flight Path Analysis
Major Adam Cybanski - Canada
Directorate of Flight Safety - Canadian Forces
11：30 Questions／Discussion from the floor
1：30 Post-Turbulence Structural Integrity Evaluation
Ray Chang／C. Edward Lan／Wen-Lin Guan –
Republic of China
2：00 Building Partnerships in Unmanned Aviation Systems
Tom Farrier - USA
Chair, ISASI UAS WG
2：30 Regulatory Runway Incursion Awareness Systems
Robert Joslin - USA
Chief Scientific & Technical Advisor
Flight Deck Technology Integration – FAA
3：30 Helicopter Design for Maintainability
Andrés Serrano - Brazil

4：00　Questions／Discussion from the floor
4：30　ISASI Working Group Meetings

Thursday Sept. 15

8：30　B-787 Safety Presentation
Thomas Dodt - USA
Chief Engineer - Air Safety Investigation
Boeing Commercial Airplanes
9：00　Human Errors & Criminal Guilt
Yukiko Kakimoto - Japan
Institute of Human Factors
9：30　Pilots' Cognitive Processes for Making In-flight Decisions under Stress
Wen-Chin Li PhD – Republic of China
National Defence University
10：30　Human Factors Standardized Procedures
Helena Reidmar – USA
First Officer – Delta Airlines
11：00　"Back to Basics" Still Work?
Mont Smith - USA
Director Safety - ATA
11：30　Questions／Discussion from the floor
1：00　ISASI Business Meeting （ISASI Members）
1：30　Update on the AF 447 Investigation
BEA - France
3：00　An Investigation media／communications Strategy
Ian Sangston – Australia
General Manager ASI – ATSB
3：30　Media in a High Profile Accident
Thierry Thoreau - France
Director, Flight Safety
AIRBUS SAS
4：00　Questions／Discussion from the floor
4：30　Seminar Closing

參、會議重點及心得摘要

會議開始由大會主席 Frank Del Gandio 致詞後，國際民航組織（ICAO）事故調查處處長 Marcus Costa 先就國際民航組織在事故調查區域合作方面之發展作一報告。Marcus 表示，ICAO 於今年 3 月 20 日公布 Manual on Regional Accident and Incident Investigation Organization （Doc 9946），簡稱為 RAIO。ICAO 推動事故調查區域合作之目的乃因全球某些區域之國家尚未具備完整之飛航事故調查能量，或未有足夠的資源獨立完成事故調查，則可由臨近區域的數個國家共同組成區域性的事故調查組織，共同合作以完成事故調查。對於區域事故調查組織的組成，ICAO 要求該事故調查組織須在運作上和民航主管機關分隔，以達獨立調查之精神。且區域事故調查組織簽署合作協議後須送交國際民航組織註冊。

會議接著進入專題報告議程，本會去年執行國科會科發計畫，其中人為因素子計畫和國防大學李文進博士共同就飛行員決策下達方面進行研究，並在此次年會中發表研究結果。論文名稱為 Pilots’ Cognitive Processes for Making In-flight Decisions under Stress，主要是在探討飛行員在遭遇到不同飛航情境的狀況下，如何籍由不同方式產生決策。各專題報告之內容摘要節錄如下：

飛行員在壓力下產生飛行決策的認知過程

近年來，學者研究發現，約 69%的飛航事故和飛行員的飛行決策錯誤有關。

航空知識、技能和判斷一向被視為飛行員必須具備的三個基本能力，而航空知識和操作技能通常在飛行員養成訓練時會是訓練重點項目，但飛行員於遭遇問題時的判斷力及決策下達能力則較不易在初始訓練中完成，除個人心理素質及能力外，經驗的累積

及提供決策下達的方法往往是提升飛行員決策下達能力較有效之方法。

共有 157 名飛行員參加了這項研究，包括 57 位正駕駛員長和 99 位副駕駛員。在研究之初，先提供參與研究的飛行員 4 種產生飛行決策的方法：

1. SHOR（Stimuli, Hypotheses, Options, Response）記憶方法（ mnemonic），包括四個步驟：刺激、假設、選項和回應。SHOR 記憶方法最初是由美國空軍開發使用，主要協助飛行員在高度壓力及時間有限的情況下作出決策。在此情況下，決策的下達需要依威脅即時反應，重新安排任務並隨時的修正。

2. PASS （Problem identification （define／redefine problems）; Acquire information （seek more information）; Survey strategy （survey／resurvey strategies）; Select strategy） 記憶方法最初是由達美航空（Delta）開發作爲民航飛行員 CRM 培訓計畫的一部分。它包括四個步驟：問題識別（定義／重新定義問題）；獲取資訊（尋找更詳細的資訊）；審視策略（調查／重新審視戰略）；選擇策略。

3. FOR-DEC （ Facts, Options, Risks & Benefits, Decision, Execution, Check）記憶方法的 6 個組成步驟爲：事實、選項、風險與利益、決策、執行、檢查。當飛行員在飛行中處理突發的狀況時，FOR-DEC 會協助飛行員評估時間壓力的影響、不斷改變的飛航環境、和資訊不完整時，所包含的風險和益處的分析。

4. DESIDE （Detect, Estimate, Set safety objectives, Identify, Do, Evaluate）記憶方法爲依南非飛行員的樣本所發展的方法，包括 6 個步驟：檢測、估計、設置安全目標、識別、執行、評估。DESIDE 方法是以飛行員飛行決策衝突理論模型所發展的實際應用。

參與研究的飛行員在了解 4 種不同的決策記憶方法後，將其運用於 6 個不同的飛行情境中，並依運用不同方法所需時間及適用性評估各記憶方法的成效。評估結果顯示飛行員對 4 種記憶方法皆有正面的評價，以有系統的方式提供決策下達的指引及訓練，可以協助飛行員於遭遇不正常狀況時，能有系統的評估風險、運用資源，以得到較佳的決策結果。

跨國合作飛航事故調查

冰島事故調查局的主任調查官 Thorkell Agustsson 提報發生在距離其辦公室 5,400 英里外，一架波音 747-300 事故調查的經驗。Agustsson 表示，冰島事故調查局單位很小，僅有 2 名調查員、3 名董事會成員和一名受雇的兼職秘書，但此案依據國際民航公約第 13 號附約進行事故調查，使整個調查過程相當順利。

2008 年 3 月，一架冰島註冊的波音 747 航機自沙烏地阿拉伯飛往孟加拉的定期的航班，在孟加拉首都的齊亞國際機場降落滾行時 3 號發動機著火，307 名乘客和 18 名組員皆安全撤離。冰島事故調查局於接到事故通報及電話會議討論後，依國際民航公約第 13 號附約，接受孟加拉民航局的委託，主導此件事故調查。

冰島事故調查局僅有 2 位飛航事故調查員，而此事故牽涉的國家很多，包括事故發生地孟加拉，航空器使用人國籍國沙烏地阿拉伯，發動機維護國馬來西亞，飛航紀錄器由英國航空事故調查局協助解讀，加上各國間有數小時的時差，造成溝通協調上的許多不便。但該案主任調查官 Agustsson 表示，由於飛航事故的調查，國際上各國皆依據國際民航公約第 13 號附約進行，使得原本非常複雜的跨國事故調查，得以非常順利由冰島事故調查局這樣的小單位主導完成。

運輸類飛機遇到嚴重的大氣湍流的結構完整性評估

本會執行科發計畫時，亦和學界合作探討航空器在遭遇不穩定氣流時，飛航資料紀錄器所記錄各項相關參數的變化，及與飛航環境中氣流參數間的關係。中華大學臧教授則在此次年會中發表航空器在遭遇不穩定氣流時，飛航資料紀錄器資料的特性，及紀錄器資料和航空器結構完整性的評估。

此論文乃假設航空器經長時間運作後，飛航環境中各種物質可能對航機結構產生腐蝕，結構亦可能因起降或其他應力作用而產生疲勞，若能自飛航資料紀錄器各項記錄的參數中，找出航機結構疲勞時，紀錄器資料可能呈現的特性，則可依檢視飛航資料的結果，在航空器顯示出可能有結構疲勞的可能性時，預先強化結構完整性，避免空中解體飛航事故的發生。

本研究運用本會已結案的事故調查報告中所公布的飛航資料，包括航空器遭遇不穩定氣流及空中解體等飛航事故的飛航資料數據，利用模糊邏輯建模方式，以複雜的工程數學計算將取得的飛航資料加以運算分析及歸納整理，以尋找航空器在解體前飛航資料所能呈現的特性。研究結果雖然歸納出某些老舊、可能結構完整性有疑慮航空器的數據特性，但要能得出當航空器飛航資料呈現此種現象，即代表該航空器結構已遭受某種程度破壞的結論，以實際應用於提升飛航空全，則有待更進一步的研究。

人為錯誤等同於刑事犯罪嗎？

日本大學的由紀子博士於大會中提出一項近年來在國際民航界被熱烈討論的議題，即飛航事故中，人為錯誤是否應等同於刑事犯罪?

2010 年 10 月 26 日，日本最高法院判決 2 名航空管制員因管制疏失而導致 2 架航空器空中接近的飛航事故，須入監服刑的案例。

2001 年 1 月 31 日，日本航空公司波音 747-400 航機，執行由東京國際機場到那霸機場的定期載客任務，起飛後往 37,000 呎的高度爬升。同時，另一架日航麥道 DC10 航機自韓國釜山國際機場飛往東京國際機場，巡航高度亦爲 37,000 呎。由於管制員叫錯航班呼號，使得該 2 航班因空中接近而採取緊急避讓的措施，共造成數十人的輕重傷。

近年來，人爲因素在航空業界被廣泛的討論與研究，並實際的被運用於失事調查中。航空失事調查的重點，亦從著重於事故「操作者」本身的錯誤行爲，演變爲探討操作者工作的環境、組織及管理等因素，對操作者行爲可能造成的影響。

事件調查，特別是論及人爲因素時，很容易只追溯到是誰不當的操作或行爲導致了事件的發生，根據這樣的方法，事件預防的努力通常集中在如何減少在第一線工作人員的不安全動作或行爲。然而，人是環境的產物，當意外發生時，若我們從系統或管理的角度上來看，除非工作人員蓄意違反規定，否則因技術或判斷上的失誤，皆可能是因爲當時環境的影響，或是組織的政策及給予的訓練不完整所導致。

事件調查之目標應該設定在造成或蘊育工作人員失誤的系統或管理缺口上，追求整體的改善，避免類似事件再次發生。僅追究第一線工作人員的責任，而不從改善系統面著手，不但無法有效的避免類似事故的再發生，更可能造成當事人因害怕遭受處罰而隱藏事故發生的真正原因，影響飛航安全的改善。

法航 447 之飛航紀錄器及殘骸搜尋

法國航空事故調查局在此次年會中亦提報法航 447 飛航事故的水下打撈及偵搜作業，並獲得本次大會的最佳論文獎。

2009 年 6 月 1 日，一架法航 A330-203 客機，執行自巴西里約熱內盧加利昂國際機場至

法國巴黎戴高樂機場的定期載客任務。該機載有 216 名乘客以及 12 名機組人員，該機可能於巡航高度 3,5000 呎時進入強烈的暴風雨區域並遭遇強烈的亂流，因不明原因致失事墜海。

2011 年 4 月 2 日，法國 BEA 以側掃聲納找到疑似殘骸區域並以 ROV 確認殘骸。整個水下偵搜面積達 17,000 平方公里，水深 3,900 公尺。經歷五階段偵搜的工作，共 176 天海上作業，才找到事故航機的主殘骸、紀錄器及部分遺體。整個水下偵搜及殘骸打撈費用達 3,460 萬歐元，約 14.4 億台幣。

法國航空事故調查局表示該事故調查報告預計於 2012 年年中發布。

肆、建議事項

一、發生於海上之飛航事故，殘骸打撈之技術及設備得隨事故地點環境之不同而作適當之調整，本會應在年度事故調查演練時，針對不同的事故情境，事先做好準備。

二、本會爲國際航空安全調查員協會之會員，每年皆派員參與年會，與世界各國之調查員交換調查之經驗與研究成果。建議本會繼續參與協會之活動，以保持本會於國際調查單位之互動及資訊交流之管道。

伍、附錄

年會發表之論文。

International Society of Air Safety Investigators

42nd Annual Seminar
Salt Lake City, Utah

Title of Research

Understanding Pilots' Cognitive Processes for Making In-flight Decisions under Stress

Author (s):
[1]Wen-Chin Li, Head of Graduate School of Psychology, National Defense University, Taiwan
[2]Don Harris, Managing Director of HFI Solutions Ltd., United Kingdom
[3]Yueh-Ling Hsu, Professor in the Department of Air Transportation, Kainan University, Taiwan
[4]Thomas Wang, Managing director, Aviation Safety Council, Taiwan

Abstract:

In flight operations, pilots are confronted with many problems that occur in continually changing situations that create a level of stress and lead to accidents. To make rapid decisions, pilots make decisions using a holistic process involving situation recognition and pattern matching. This research investigated 157 pilots from a B747 fleet to find out how pilots make in-flight decision in such stressful situations. The research method is based upon evaluating the situational awareness, risk management, response time and applicability of four different decision-making mnemonics in six in-flight scenarios. The data obtained in this research suggests that the FOR-DEC may be suitable as a basis for providing training which will be applicable for covering all basic types of decision. FOR-DEC was evaluated as the most applicable mnemonic-based decision making process across the six different scenarios used. It also had significantly superior performance compared with the other three mnemonic-based methods evaluated (SHOR, PASS & DESIDE) when making recognition-primed decisions, response selection decisions, non-diagnostic procedural decisions, and problem-solving decisions.

Keywords： Accident Prevention, Aeronautical Decision-making, Human Errors, Stress, Time Pressure

Introduction

The advent of improved accident investigation technology in recent years, such as cockpit voice recorders, along with a more systematic review of accident statistics, has produced a growing realization of the significance role of pilot judgment errors in flight operations （Buch and Diehl, 1984）. Jensen and Benel （1977） found that decision errors contributed to 35% of all nonfatal and 52% of all fatal general aviation accidents in the United States. Diehl （1991） proposed that decision errors contributed to 56% of airline accidents and 53% of military accidents. Furthermore, Li and Harris （2008） suggested that 69% of accidents were relevant to pilots’ in-flight decision errors. O'Hare（2003） reviewed aeronautical decision-making and came to the conclusion that 'it is difficult to think of any single topic that is more central to the question of effective human performance in aviation than that of decision-making'. Current FAA regulations require that decision-making be taught as part of the pilot-training curriculum （FAA, 1991）, however, little guidance is provided as to how that might be accomplished, and none is given as to how it might be measured, outside of the practical test.

Aeronautical knowledge, skill, and judgment have always been regarded as the three basic faculties that pilots must possess. The requisite aeronautical knowledge and operating skills have been imparted in flight training programs and have subsequently been evaluated as part of the pilot certification process. In contrast, judgment has usually been considered to be a trait that good pilots innately possess or an ability that is acquired as a by-product of flying experience. A decision bias is not a lack of knowledge, a false belief about the facts, or an inappropriate goal, nor does it necessarily involve lapses of attention, motivation, or memory. Rather, a decision bias is a systematic flaw in the internal relationship among a person's judgments, desires, and choices. Human reasoning depends, under most conditions, on heuristic procedures and representation that predictably lead to such inconsistencies. It follows that human reasoning processes are error prone by their very nature （Cohen, 1993）. Although a great deal of research has demonstrated that decision making is a primary component of pilot performance, this concern has not translated well into systematic training programs. Aviation specialists have suggested that rational judgment is a function of both motivation and information processing. Another approach to improving pilot decision making is the use of prescriptive aids such as the ARTFUL decision tree (O'Hare, 1992). However, using these assumes that sufficient time exists to proceed through a prescribed decision making checklist.

Literature Review

Time pressure has several obvious but important implications for decision-making. Firstly, decision makers will often experience high levels of stress, with the potential for exhaustion and loss of vigilance; secondly, their thinking will shift, characteristically in the direction of using less complicated reasoning strategies (Payne, Bettman, & Johnson, 1988). Stiensmeier-Pelster & Schurmann (1993) indicated that time stress may affect the process of decision making in a variety of ways depending on the type of decision. It may lead to reallocation of cognitive resources from the decision process to the stress coping process. Time stress may also change the goals of the decision-making process. Under time stress, cognitive resources may be allocated from the decision-making process to monitoring of the flow of time as part of a coping strategy (Zakay, 1993). Klein & Thordsen (1991) observed that decision makers in difficult situations and under time stress did not appear to use the classical approach to make decisions, even when they were trained in that approach. Much of the research on qualitative changes in cognitive performance, when stressors such as time pressure are present, is broadly consistent with the conflict theory of decision making proposed by Janis and Mann (1977). Edland & Svenson (1993) found that under time pressure the following changes were observed in the decision-making processes: (1) an increased selectivity of input of information; (2) attributes perceived to be more important were given more weight under time pressure than in situations with no time pressure; (3) the accuracy of human judgment decreases; (4) the use of non-compensatory decision rules becomes more frequent than compensatory rules requiring value tradeoffs; (5) there is a decrease in the ability to find alternative problem-solving strategies; (6) motivation is attenuated.

Benson and Beach (1996) found that time pressure made the screening phase of problem identification less systematic. Unsystematic identification and screening processes can also occur in decisions concerned with ill-defined problems. The quality of decision-making may suffer even more from time stress in this case. Keinan (1987) found that under stress the range of alternatives and dimensions that are considered during a decision-making process is significantly restricted, compared with normal conditions. In brief, the effects of time stress on decision making are: (1) a reduction in information search and processing; (2) increased importance of negative information; (3) defensive reactions increase, such as neglect or denial of important information; (4) bolstering of the chosen alternative occurs; (5) forgetting important data happens; (6) poor judgments and evaluation are more likely; (7) there is a tendency to use a strategy of information filtration. Information that is perceived as being the most important is processed first, and then processing is continued until time is up.

The processes of decision-making center around two elements; situation assessment, which is used as a pre-cursor to generate a plausible course of action, and mental simulation to evaluate that course of action for risk management (Endsley, 1993). If a pilot recognizes there is sufficient time for making wide-ranging considerations, s／he will evaluate the dominant response option by conducting a mental simulation to see if it is likely to work. If there is not adequate time, the pilot will tend to implement the course of action that experience (if any) dictates is the most likely to be successful. Klein (1993) found that whereas experts used a recognition-primed or perception-based decision process to retrieve a single likely option, novices were more likely to use an analytical approach, systematically comparing multiple options, and experience affects the processes of decision-making by improving the accuracy of situation assessment, increasing the quality of the courses of action considered and by enabling the decision maker to construct a mental simulation. Furthermore, Endsley (1997) defines situation awareness (SA) as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the future'. In a dynamic tactical environment, effective decision-making is highly dependent on situation awareness which has been identified as a critical decision component (Endsley & Bolstad, 1994). Situation assessment is the process by which the state of situation awareness is achieved and is a fundamental precursor to situation awareness, which is itself the precursor for all aspects of decision-making (Prince & Salas, 1997).

Automated aids in aviation industry are designed specifically to decrease pilots' workload by performing many cognitive tasks, not only including information processing, system monitoring, diagnosis and prediction, but also controlling the physical placement of the aircraft. Flight management systems (FMS) are designed not only to keep the aircraft on course, but also to assume increasing control of cognitive flight tasks, such as calculating fuel-efficient routes, navigating, or detecting and diagnosing system malfunctions. An inevitable facet of these automated aids is that they change the way pilots perform tasks and make decisions. However, the presence of automated cues also diminishes the likelihood that decision makers will make the cognitive effort to process all available information in cognitively complex ways. Parasuraman and Riley (1997) describe this tendency toward over-reliance as 'automation misuse'. In addition, automated cues increase the probability that decision makers will cut off situation assessment prematurely when prompted to take a course of action by automated aids. Automation commission errors are errors made when decision makers inappropriately follow automated information or directives (e.g., when other information in the environment contradicts or is inconsistent with the automated cue). These errors have recently begun surfacing as by-products of automated systems. Experimental evidence of automation-induced commission errors has also been provided by full-mission simulations in the NASA Ames Advanced Concepts Flight Simulator (Mosier, Skitka, Heers and Burdick, 1998).

Orasanu and Fisher (1997) investigated the five highest performance pilots and the five lowest performance pilots in a flight simulation study, and found a tendency for high performance pilots to be more likely to use low workload situations to make plans and collect more relevant information compared with the poorer performing pilots. High performance pilots also demonstrated greater situation awareness.

Method

Participants:

There were 157 pilots participated in this research, consisting of 57 captains and 99 first officers. Data was missing for one participant. The full demographic data collected including teaching experience, flying hours, and training background.

Four Aeronautical Decision-making Mnemonics：

The SHOR mnemonic （Wohl, 1981） consists of four steps： Stimuli, Hypotheses, Options, and Response. It was originally developed for use by U.S. Air Force tactical command and control, where decisions were required under high pressure and severe time constraint. In this situation, decisions require near-real-time reactions involving threat warning, task rescheduling and other types of dynamic modification. The SHOR methodology is basically an extension of the stimulus-response paradigm of classical behavioral psychology developed to deal with two aspects of uncertainty in the decision-making process, information input uncertainty followed by the evaluation of the consequences of actions, which creates the requirement for option generation and evaluation.

The PASS methodology was originally developed by a civil airline （Delta） to train pilots as part of a CRM training program. It consists of four steps：Problem identification （define／redefine problems）; Acquire information （seek more information）; Survey strategy （survey／resurvey strategies）; Select strategy （Maher, 1989）. After the selection of a solution strategy, if the problem is not solved, then the pilot should re-enter the problem solving loop once more.

The FOR-DEC mnemonic comprises of six steps： Facts, Options, Risks & Benefits, Decision, Execution, Check （Hormann, 1995）. It incorporates an analysis of risk and benefits when handling in-flight situations, including assessing the effects of time pressure, continually changing conditions, distraction, and having incomplete information.

The DESIDE （Murray, 1997） was developed on a sample of South African pilots and comprises of six steps： Detect, Estimate, Set safety objectives, Identify, Do, Evaluate. The DESIDE method is a practical application to aid pilots in making in-flight decisions adapted from conflict-theory model of Janis and Mann （1977）.

The Development of Six In-flight Scenarios：

To develop scenarios for assessing the effectiveness of the ADM mnemonics which corresponded to Orasanu’s （1993） six generic decision making categories, six focus groups were conducted, one for each scenario. Each focus group comprised two human factors specialists, three senior B-747 instructor pilots and the director of Crew Resource Management Departments of the participating airlines. The purpose of these focus groups was to ensure enough detailed information for pilots was included to enable them to make a decision and hence to evaluate the performance of the four ADM mnemonics. These six scenarios developed were as follows.

Go／no go decisions： A Boeing 747-400 departed from Taipei to Los Angeles, take-off weight 833,000 pounds. The warning light of 4L door suddenly illuminated while the aircraft was taking off from Taoyuan Airport runway 05 with an indicated air speed of 120 kt.……

Recognition-primed decisions： A Boeing 747-400 departed from Los Angeles to Taipei with landing weight 533,000 pounds. The aircraft planed to land at Taoyuan Airport runway 06, visibility 3,000 meters, cloud base 500 feet. Auto pilot engaged during instrument approach, ILS signal is suffering interference and Glide Slope indication is fluctuating……

Response selection decisions： A Boeing 747-400 departed from Hong Kong to Taipei, and planned to land at Taoyuan Airport runway 05 with landing weight 533,000 pounds. The ATC cleared "Direct to TONGA, descend and maintain flight level 290, clear to JAMMY via TONGA 3A RNAV ARRIVAL". When aircraft is 3 miles from TONGA, communication was is lost, and there is a failure to contact ATC……

Resource management decisions： A Boeing 747-400 departed from Hong Kong to Taipei, and planed to land at Taoyuan Airport runway 05 with landing weight 533,000 pounds. ATC cleared "Direct to TONGA"; descend and maintain 11,000 feet; clear to JAMMY via "TONGA 3A RNAV ARRIVAL". 3 miles before BRAVO, the Captain （PF） suddenly became incapacitated, and provided no response to standard CALL OUT twice ……

Non-diagnostic procedural decisions： A Boeing 747-400 departed from Taipei to Los Angeles, from Taoyuan Airport runway 05 with take-off weight 833,000 pounds at 22：30 local time. When climbing to 1,000 feet with Thrust Reduced to CLB, the aircraft suddenly began to vibrate significantly. PM found No.1 ENG vibration indication abnormal, although other ENG indications were normal. By this time the aircraft has cross through a cloudy area with light turbulence. It was difficult to judge whether vibration caused by ENG or turbulence; it was unclear whether to continue to destination airport or return to base……

Problem-solving decisions： A Boeing 747-400 departed from Taipei to Los Angeles, from Taoyuan Airport runway 05 with take-off weight 833,000 pounds. During the climb through 1,000 feet after departure, the fire warning system of No.4 ENG was activated, 10 seconds later, the aircraft began to vibrate heavily and a big "BANG" was heard. The relevant No.4 ENG systems failed totally, and the fire warning disappeared.....

ADM Evaluation Instruments

To develop a rating instrument for the subsequent evaluation of the suitability of the four ADM mnemonic-based methods in the six in-flight scenarios, six focus groups were formed, one for each scenario. Each comprised two human factors specialists and three B-747 instructor pilots. The six selected scenarios were analyzed by the focus group members using all four mnemonic methods. This process provided the material for the construction of a rating form to evaluate the suitability of the ADM mnemonics for decision-making training. The narrative responses describing the decision-making process by which the participants would arrive at their decision was evaluated using the criteria of situation assessment, risk management, response time and applicability.

Administration of Evaluation Forms

As a result of the length of the scenarios and the number of ratings required, each participant only evaluated the ADM decision techniques in three scenarios, either scenarios 1, 3 & 5 or scenarios 2, 4 & 6. The ADM rating forms were distributed to all pilots of B-747 fleet of the participating airlines. Completed instruments were returned to the Crew Resource Management Department. For each participant an overall score for each mnemonic method in each scenario was created by summing the scores across four dimensions of situation assessment; risk management; response time; and applicability giving a potential range of scales between 4 （low suitability） to 36 （high suitability）.

RESULTS

Sample Characteristics

In total, data were collected from 1,871 evaluations of scenarios. There were 312 completed rating forms for the go／no go decisions scenario; 311 for the recognition-primed decision-making scenario; 316 for the response selection decision-making scenario; 310 for the resource management scenario; 312 for the non-diagnostic procedural decisions-making scenario, and 310 completed rating forms for the creative problem-solving scenario (Table 1).

Table 1 The Mean Scores and Standard Deviations for four Different Mnemonics decision-making methods in each of the Six Scenarios.

Item	*N*	*M*	*SD*
Scenario 1 SHOR	79	6.67	1.39
Scenario 1 PASS	78	6.42	1.63
Scenario 1 FORDEC	77	6.83	1.67
Scenario 1 DESIDE	78	6.43	1.51
Scenario 2 SHOR	78	6.41	1.56
Scenario 2 PASS	78	6.59	1.25
Scenario 2 FORDEC	77	6.99	1.30
Scenario 2 DESIDE	78	6.75	1.27
Scenario 3 SHOR	79	6.59	1.14
Scenario 3 PASS	79	6.81	1.03
Scenario 3 FORDEC	79	7.43	1.10
Scenario 3 DESIDE	79	6.99	1.21
Scenario 4 SHOR	77	6.83	1.47
Scenario 4 PASS	77	6.67	1.27
Scenario 4 FORDEC	78	7.11	1.41
Scenario 4 DESIDE	78	6.91	1.40
Scenario 5 SHOR	78	6.47	1.31
Scenario 5 PASS	78	6.72	1.11
Scenario 5 FORDEC	78	7.50	1.14
Scenario 5 DESIDE	78	7.08	1.09
Scenario 6 SHOR	77	6.81	1.46
Scenario 6 PASS	78	6.73	1.25
Scenario 6 FORDEC	77	7.20	1.33
Scenario 6 DESIDE	78	6.94	1.19

Scenario 1： Go／no go Decisions

The highest overall rating of suitability for the ADM mnemonics in the go／no go decision-making scenario by participants was FORDEC followed by SHOR, DESIDE, and PASS (Table 1). There were no significant differences in the ratings of suitability among the four ADM mnemonics ($F=2.192, P>.05$) in table 2.

Table 2： One-way ANOVA table for Go／no go scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	8.963	2.243	3.997	2.192	.108	
SS_b	430.394	76	5.663	3.106	.045	NS
SS_E	310.694	170.430	1.823			
SS_T	750.051	248.673	11.483			

Scenario 2： Recognition-primed Decision

The highest overall rating of the suitability for the ADM mnemonics by participants was for FOR-DEC followed by DESIDE, PASS, and SHOR （Table 1）. There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario （F=5.22, P<.007）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC（M=6.99, SD=1.30） vs SHOR （M=6.41, SD=1.56）; and FOR-DEC （M=6.99, SD=1.30） vs PASS （M=6.59, SD=1.25） in table 3.

Table 3： One-way ANOVA table for Recognition-primed scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	13.116	1.962	6.684	5.223	.007	
SS_b	365.685	76	4.812	3.759	.028	FOR-DEC>SHOR
SS_E	190.832	149.129	1.280			FOR-DEC>PASS
SS_T	569.633	227.091	12.776			

Scenario 3： Response Selection Decision

The highest overall rating of suitability for the ADM mnemonics by participants was for FOR-DEC followed by DESIDE, PASS, and SHOR （Table 1）. There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（F=14.63, P<.000）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC （M=7.43, SD=1.10）vs SHOR（M=6.59, SD=1.14）; FOR-DEC(M=7.43, SD=1.10）vs PASS（M=6.81, SD=1.03） ; and FOR-DEC（M=7.43, SD=1.10） vs DESIDE （M=6.99, SD=1.21） in table 4.

Table 4： One-way ANOVA table for Response Selection scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	30.296	3	10.099	14.637	.000	FOR-DEC>SHOR FOR-DEC>PASS FOR-DEC>DESIDE
SS_b	235.322	78	3.017	4.372	.007	
SS_E	161.443	234	.690			
SS_T	427.061	315	13.806			

Scenario 4： Resource Management Decision

The highest overall rating of suitability for the ADM mnemonics in the resource management decision-making scenario by participants was FORDEC followed by DESIDE, SHOR, and PASS （Table 1）. There were no significant differences in the ratings of suitability among the four ADM mnemonics（F=2.639, P>.05）in table 5.

Table 5： One-way ANOVA for Resource Management scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	7.833	2.120	3.695	2.639	.071	NS
SS_b	368.648	76	4.851	3.465	.034	
SS_E	225.542	161.106	1.400			
SS_T	602.023	239.226	9.946			

Scenario 5： Non-diagnostic Procedural Decision

The highest overall rating of suitability for the ADM mnemonics by participants was FOR-DEC followed by DESIDE, PASS, and SHOR （Table 1）. There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（F=20.494，P<.000）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC （M=7.50, SD=1.14） vs SHOR （M=6.47, SD=1.31）；FOR-DEC （M=7.50, SD=1.14） vs PASS （M=6.72, SD=1.11）； and FOR-DEC （M=7.50, SD=1.14） vs DESIDE （M=7.08, SD=1.09） in table 6.

Table 6： One-way ANOVA for Non-diagnostic Procedural scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*

SS_{tr}	45.491	2.183	20.840	20.494	.000	FOR-DEC>SHOR
SS_b	253.880	76	3.341	3.285	.039	FOR-DEC>PASS
SS_E	168.696	165.896	1.017			FOR-DEC>DESIDE
SS_T	468.067	244.079	25.198			

Scenario 6： Problem-solving Decision

The highest overall rating of suitability for the ADM mnemonics by participants was FOR-DEC followed by DESIDE, PASS, and SHOR （Table 1）. There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（F=3.379， P<.032）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC （M=7.50, SD=1.14） vs PASS （M=6.72, SD=1.11） in table 7.

Table 7： One-way ANOVA for Problem-solving scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	8.593	2.222	3.867	3.379	.032	
SS_b	307.459	75	4.099	3.583	.028	FOR-DEC>PASS
SS_E	190.704	166.655	1.144			
SS_T	506.756	243.877	9.11			

DISCUSSION

In flight operations, pilots are confronted with many problems that occur in continually changing situations that do create certain level of stress and leading to human error accidents. To make rapid decisions, pilots make decisions using a holistic process involving situation recognition and pattern matching. Within this framework, pilots’ situation awareness becomes the driving factor in the decision-making process. In general, aviation training organizations do not have specific methods or techniques for decision-making instruction during ab-initio training. The ability to make decisions in the air has often been regarded as by-product of flying experience rather than training. However, the data obtained in this research, , suggests that the FOR-DE may be suitable as a basis for providing training which will be applicable for covering all six basic types of decision. FOR-DEC was evaluated as being the highest-rated scale for its applicability across six different decision-making scenarios. It was rated as potentially having superior performance compared to the other three mnemonic methods （SHOR, PASS & DESIDE） in Go／no go decision, Recognition-primed decisions, Response selection decision, Non-diagnostic procedural decision, and Problem-solving decision scenarios （Table 8）.

Table 8： Summary of rankings of the five ADM mnemonic methods across the six decision making scenarios

Scenarios / Mnemonics	Go／no go decision	Recognition-primed decision	Response selection decision	Resource management decision	Non-diagnostic procedural decision	Creative problem -solving
SHOR	2	4	4	3	4	4
PASS	4	3	3	4	3	3
FOR-DEC	1	1	1	1	1	1
DESIDE	3	2	2	2	2	2

Kaempf & Orasanu （1997） suggested that under conditions of time pressure, decision makers need help to determine what is occurring in the environment around them. Therefore, decision aids and training should provide decision makers with the tools and skills necessary to accurately and quickly make situation assessments. FOR-DEC was rated highly for situation assessment, risk management, and applicability. It was thought to be comprehensive and thorough; clear about how to identify the safest actions; and it also had a logical order and was easy to remember. However, it did require much more time to perform this analysis and produce a response. The qualitative data suggest that SHOR was regarded by pilots as providing a method for a quick decision-making response in urgent situations with a logical order for flight operations safely. PASS also matched airlines pilots training guidelines as it had clear and specific procedures to follow. DESIDE were regarded as being comprehensive but enough time was needed to undertake this method. FOR-DEC was rated as the highest performance of all mnemonics.

Pilots advised that practicing FOR-DEC in the simulator was extremely important before attempting to apply it in a real life situation. FOR-DEC was rated by cadet pilots as the best ADM mnemonic－based decision making method for promoting good resource management decisions as would be expected of a methodology originally developed to promote good CRM. The qualitative data elicited from pilots’ showed that FOR-DEC has characteristics to deal with non-urgent situations as a result of its good situation assessment and risk management characteristics; it was thought that it prompted a comprehensive approach in terms of the number of factors that it encompassed in the decision making process; it was regarded as providing a specific and clear approach to analyze a situation and it possessed a logical order that was easy to remember. However, it did require more time to undertake the required steps and analyze and respond to the changing situation. An implication of the fact that many decisions must be made under stress is that training should include extensive practice to learn key behaviors (Driskell & Salas, 1991). However, Zakay & Wooler (1984) found that practice without time pressure did not enhance decision-making under time constraints. This suggests that, if decision-making is likely to be required under time pressure or other stressful conditions, practice should include task performance under those conditions.

SHOR was developed for use in U.S. Air Force tactical command and control scenarios, where decisions were likely to be made under high pressure and within severe time constraints. These situations involve making near-real-time decisions involving threat warning and rescheduling, and often require dynamic modifications to plans (Wohl, 1981). The contents of SHOR match the requirements of the scenarios requiring urgent decisions. As SHOR is basically an extension of the stimulus-response (S-R) paradigm of classical behaviourist psychology, it explicitly addresses the requirement to deal with two aspects of uncertainty in the decision-making process; information input uncertainty (relating to hypothesis generation and evaluation) and consequence-of-action uncertainty (which creates the requirement for option generation and evaluation) (Wohl, 1981). SHOR is able to promote quick responses in a time-limited situation and it also corresponds to the basic principles of briefing during tactical training. The qualitative data from pilots also revealed that the four steps in SHOR fulfilled the requirements to deal with time-limited, urgent situations. It has simple steps with high applicability; it is easy to practice and it promotes the logical procedures required for safe action. Payne, Bettman, and Johnson (1988) found that, under time pressure, a number of heuristic choice strategies are more useful than attempts to apply a truncated normative model. Subjects adapt their decision-making strategies in reasonable ways when placed under time constraints. Under time pressure, the likelihood of making serious errors increases. Decision makers tend to ignore relevant information, make risky decisions and perform with less skill (Keinan, 1987).

Pilots consistently selected FOR-DEC as the best mnemonic-based decision making method in the go／no go decision, recognition-primed decision, response selection decision, resource management decisions, non-diagnostic procedural decision scenarios, and problem-solving decision all of which were urgent, potentially high risk, time-critical situations and required prompt actions. The pilots' comments suggested that FOR-DEC had the required characteristics to deal with urgent situations as it promoted quick responses. It was simple and easy to remember; it fitted the constraints inherent in time-limited and critical situations; it matched the general format of a pre-flight briefing; it was easy to put into practice; and it was thought that its logical procedures promoted safe action. The principal limitation of the present study was that it only elicited pilots' opinions about the efficacy of these decision-making techniques. As a result, research needs to be undertaken to produce empirical performance data to establish if training in the use of ADM mnemonic-based methods such as FOR-DEC can actually improve pilots' in-flight decision-making. There is a raising need for future study to justify the effectiveness of ADM training interventions based FOR-DEC mnemonics methods across all different types of decision-making scenarios encountered in stress situations. The cognitive processes employed by pilots also need to been investigated in a series of reliable tools.

CONCLUSIONS

Orasanu (1993) suggested that the six basic types of decisions each impose different demands on the decision-maker and require different approaches. This research suggests that the FOR-DEC mnemonic forms a suitable basis for decision-making training that encompass the requirements for these six basic decision making situations. It was rated as being the best ADM mnemonic method in critical, urgent situations and was regarded as superior for knowledge-based decisions which required more comprehensive considerations. To optimize the effectiveness of decision-making training, it is suggested that it will be necessary to deliver instruction using the FOR-DEC mnemonic-based method.

REFERENCES

Benson, L. and Beach, L.R. (1996), 'The Effects of Time Constraints on the

Pre-choice Screening of Decision Options', *Organizational Behaviour and Human Decision Processes,* Vol. 67, No. 2, pp. 222-228.

Buch, G. and Diehl, A. （1984）, 'An Investigation of the Effectiveness of Pilot Judgment Training', *Human Factors,* Vol. 26 （5）, p. 557-564.

Cohen, M.S. （1993）, 'Three Paradigm for Viewing Decision Biases', in Klein, G.A., Orasanu, J., Calderwood, R., and Zsambok, C.E. （Editor）, *Decision Making in Action： Models and Methods* , Ablex, Norwood, New Jersey, pp. 36-50.

Diehl, A. （1991）, 'The Effectiveness of Training Programs for Preventing Aircrew Error', in Jensen, R.S. （Editor）, *Sixth International Symposium on Aviation Psychology,* Vol. 2, Columbus, Ohio, U.S.A., The Ohio State University , p. 640-655.

Driskell, J. and Salas, E. （1991）, 'Group decision making under stress', *Journal of Applied Psychology,* Vol. 76, pp. 473-478.

Edland, A. and Svenson, O. （1993）, 'Judgment and Decision Making under Time Pressure： Studies and Findings', in Svenson, O. and Maule, A.J. (Editor), *Time Pressure and Stress in Human Judgment and Decision Making*, Plenum, New York, pp. 27-40.

Endsley, M.R. (1997), 'The Role of Situation Awareness in Naturalistic Decision Making', in Zsambok, C.E. and Klein, G. （Editor）, *Naturalistic Decision Making*, Lawrence Erlbaum, Mahwah, p. 269-284.

Endsley, M.R. （1993）, 'A survey of Situation Awareness Requirements in Air-to-Air Combat Fighters', *The International Journal of Aviation Psychology,* Vol. 3 （2）, p. 157-168.

Endsley, M.R. and Bolstad, C.A. （1994）, 'Individual Differences in Pilot Situation Awareness', *The International Journal of Aviation Psychology,* Vol. 4, （3）, p. 241-264.

Federal Aviation Administration （1991）, *Aeronautical Decision-making*, Report no. Advisory Circular 60-22, US Department of Transport, Washington.

Hormann, H.J. (1995), 'FOR-DEC： a perspective model for aeronautical decision making ', in Fuller, R., Johnston, R., and McDonald, N. （Editor）, *Human Factors in Aviation Operations*, Ashgate Publishing, Aldershot, England, pp. 17-23.

Janis, I.L. and Mann, L. （1977）, *Decision making： A Psychological Analysis of Conflict, Choice, and Commitment*, Free Press, New York.

Jensen, R. and Benel, R. （1977）, *Judgment Evaluation and Instruction in Civil*

Pilot Training, Federal Aviation Administration, Washington, D.C.

Kaempf, G.L. and Orasanu, J. （1997）, 'Current and Future Applications of Naturalistic Decision Making', in Zsambok, C.E. and Klein, G. （Editor）, *Naturalistic Decision Making*, Lawrence Erlbaum, Mahwah, p. 81-90.

Keinan, G. （1987）, 'Decision-making under Stress： Scanning Alternatives under Controllable and uncontrollable Threats', *Journal of Personality and Social Psychology,* Vol. 52, No. 3, pp. 639-644.

Klein, G.A. （1993）, 'A Recognition-Primed Decision （RPD） Model of Rapid Decision Making', in Klein, G.A., Orasanu, J., Calderwood, R., and Zsambok, C.E. （Editor）, *Decision Making in Action： Models and Methods*, Ablex, Norwood, New Jersey, p. 138-147.

Klein, G. and Thordsen, M.L. （1991）, 'Representing Cockpit Crew Decision Making', in Jensen, R.S. （Editor）, *Sixth International Symposium on Aviation Psychology,* Vol. 2, Columbus, Ohio, U.S.A., The Ohio State University, pp. 1026-1031.

Li, W-C. and Harris, D. （2008）, 'The Evaluation of the Effect of a short Aeronautical Decision-making Training Program for Military Pilots', *International Journal of Aviation Psychology,* Vol. 18 （2）, p.135-152.

Li, W-C. and Harris, D. （2005）, 'Aeronautical Decision-Making： Instructor-Pilot Evaluation of Five Mnemonic Methods', *Aviation Space Environmental Medicine,* Vol. 76 （12）, p. 1156-1161.

Maher, J. （1989）, 'Beyond CRM to Decisional Heuristics： An Airline Generated Model to Examine Accidents and Incidents Caused by Crew Errors in Deciding', in Jensen, R.S. （Editor）, *Fifth International Symposium on Aviation Psychology,* Vol. 2, Columbus, Ohio, The Ohio State University, pp. 439-444.

Maurino, D.E., Reason, J., Johnston, N., and Lee, R.B. （1995）, *Beyond Aviation Human Factors*, Ashgate Publishing, England.

Mosier, K.L., Skitka, L.J., Heers, S. and Burdick, M. （1998）, Automation Bias： Decision Making and Performance in High-Tech Cockpits. *The International Journal of Aviation Psychology*, 8, p. 47-63.

Murray, S.R. （1997）, 'Deliberate Decision Making by Aircraft Pilots： A simple Reminder to Avoid Decision Making Under Panic', *The International Journal of Aviation Psychology,* Vol. 7, No. 1, pp. 83-100.

O'Hare, D. （2003）, 'Aeronautical Decision Making： Metaphors, Models, and Methods', in Tsang, P.S. and Vidulich, M.A. （Editor）, *Principles and Practice of Aviation Psychology： Human Factors in Transportation*, Lawrence Erlbaum, New Jersey, p. 201-237.

O'Hare, D. (1992), 'The Artful Decision Maker： A Framework Model for Aeronautical Decision Making', *The International Journey of Aviation Psychology,* Vol. 2, No. 3, pp. 175-192.

Orasanu, J. and Connolly, T. (1993), 'The Reinvention of Decision Making', in Klein, G.A., Orasanu, J., Calderwood, R., and Zsambok, C.E. (Editor), *Decision Making in Action： Models and Methods*, Ablex, Norwood, New Jersey, p. 3-20.

Orasanu, J. and Fischer, U. (1997), 'Finding Decisions in Natural Environments： The View From the Cockpit', in Zsambok, C.E. and Klein, G. (Editor), *Naturalistic Decision Making*, Lawrence Erlbaum, Mahwah, p.343-358.

Parasuraman, R. and Riley, V. (1997), 'Humans and automation： use, misuse, disuse, abuse ', *Human Factors,* Vol. 39, p.230-253.

Payne, J.W., Bettman, J.R. and Johnson, E.J. (1988), 'Adaptive Strategy Selection in Decision-making', *Journal of Experimental Psychology： Learning, Memory and Cognition,* Vol. 14, p. 534-552.

Prince, C. and Salas, E. (1997), 'Situation Assessment for Routine Flight and Decision Making', *International Journal of Cognitive Ergonomics,* Vol. 1 (4), p. 315-324.

Shappell, S.A. and Wiegmann, D.A. (2004), 'HFACS Analysis of Military and Civilian Aviation Accidents ： A North American Comparison', *International Society of Air Safety Investigators,* Australia, Queensland, p. 2-8.

Stiensmeier-Pelster, J. and Schurmann, M. (1993), 'Information Processing in Decision Making under Time Pressure： The Influence of Action Versus State Orientation', in Svenson, O. and Maule, A.J. (Editor), *Time Pressure and Stress in Human Judgment and Decision Making*, Plenum, New York, pp. 241-253.

Wohl, J.G. (1981), 'Force management decision requirements for air force tactical command and control', *IEEE Transactions on Systems, Mans, and Cybernetics,* Vol. SMC-11, pp. 618-639.

Zakay, D. (1993), 'The Impact of Time Perception Processes on Decision Making under Time Stress', in Svenson, O. and Maule, A.J. (Editor), *Time Pressure and Stress in Human Judgment and Decision Making*, Plenum, New York, pp. 59-72.

Zakay, D. and Wooler, S. (1984), 'Time Pressure, Training and Decision Effectiveness', *Ergonomics,* Vol. 27, pp. 273-284.