行政院及所屬各機關出國報告
（出國類別：考察）

參加國際航空安全調查員協會 2001 年會報告

服務機關：行政院飛航安全委員會

出國人職　稱：組　長、工程師

姓　　名：周光燦、張國治

出國地區：加拿大維多利亞市

出國期間：民國九十年九月十五日至廿三日

報告日期：民國九十年十月八日

行政院及所屬各機關出國報告提要　　系統識別號
出國報告名稱：參加國際航空安全調查員協會 2001 年會報告
頁數______頁含附件：是

出國計畫主辦機關：行政院飛航安全委員會
聯絡人：鄧嵐嵐　　　　　　　電　話：(02) 2547-5200ex.175

出國人員姓名：周光燦、張國治
服務機關：行政院飛航安全委員會
單位：________________
職稱：組長、工程師　　　電話：(02) 2547-5200

出國類別：☐1 考察☐2 進修☐3 研究☐4 實習☑5 其他

出國期間：民國九十年九月十五日至廿三日
出國地區：加拿大維多利亞市

報告日期：民國九十年十月八日

分類號/目

關鍵詞：ISASI、飛安、調查員、年會、國際會議、航空安全

內容摘要：（二百至三百字）

國際航空安全調查員協會（International Society of Air Safety Investigators - 簡稱 ISASI）係於一九六四年在美國創立，現已發展為一國際專業組織，會員包括：各國民航主管機關、飛安及失事調查機關、航空器及引擎製造廠、航空公司及研究機構人員。該協會每年秋季舉行年會，由會員輪流主辦，每次年會參加人數近三百人，因該會年會豐富專業內容，參加人士日益增加。

為增加國內外專業人士之交流與互動機會，並就相關議題闡述各自經驗與心得達到分享資訊，實有必要邀請國際專業人士來台，以收一舉數得之效。故我國於一九九九年在美國波士頓之年會中爭取主辦二〇〇二年會，且已獲該協會決議通過。為圓滿完成此一國際會議，籌備工作已經於今年三月展開。

國際航空安全調查員協會本次年會於九十年九月十六日至廿一日在加拿大維多利亞市舉行。本會為瞭解調查技術之發展趨勢，加強與國外同業之交流與聯繫，並藉此瞭解專業會議進行所有細節，作為辦理明年年會之參考。

本文電子檔已上傳至出國報告資訊網

公務出國報告審核表

出國報告名稱：參加國際航空安全調查員協會2001年會報	
出國計畫主辦機關名稱：行政院飛航安全委員會	
出國人姓名/職稱/服務單位：周光燦/飛航安全官等2人	
出國計畫主辦機關審核意見	☑1. 依限繳交出國報告 ☑2. 格式完整 ☑3. 內容充實完備 ☑4. 建議具參考價值 ☐5. 送本機關參考或研辦 ☐6. 送上級機關參考 ☐7. 退回補正，原因：☐←不符原核定出國計畫　☐↑以外文撰寫或僅以所蒐集外文資料為內容　☐→內容空洞簡略　☐↓未依行政院所屬各機關出國報告規格辦理　☐°未於資訊網登錄提要資料及傳送出國報告電子檔 ☐8. 其他處理意見：
層轉機關審核意見	☐同意主辦機關審核意見　☐全部　☐部分__________（填寫審核意見編號） ☐退回補正，原因：____________（填寫審核意見編號） ☐其他處理意見：

說明：

一、出國計畫主辦機關即層轉機關時，不需填寫「層轉機關審核意見」。

二、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

三、審核作業應於出國報告提出後二個月內完成。

目　　　　次

壹、目的

國際航空安全調查員協會（International Society of Air Safety Investigators - 簡稱 ISASI）係於一九六四年在美國創立，現已發展為一國際專業組織，會員包括：各國民航主管機關、飛安及失事調查機關、航空器及引擎製造廠、航空公司及研究機構人員。該協會每年秋季舉行年會，由會員輪流主辦，每次年會參加人數近三百人，因該會年會豐富專業內容，參加人士日益增加。

為增加國內外專業人士之交流與互動機會，並就相關議題闡述各自經驗與心得達到分享資訊，實有必要邀請國際專業人士來台，以收一舉數得之效。故我國於一九九九年在美國波士頓之年會中爭取主辦二〇〇二年會，且已獲該協會決議通過。為圓滿完成此一國際會議，籌備工作已經於今年三月展開。

國際航空安全調查員協會本次年會於十九年九月十六日至廿一日在加拿大維多利亞市舉行。本會為瞭解調查技術之發展趨勢，加強與國外同業之交流與聯繫，並藉此瞭解專業會議進行所有細節，作為辦理明年年會之參考。

貳、過程

本次 ISASI 年會係第卅二屆，由加拿大航空公司駕駛員協會（Canadian Air Lines Pilot Association）主辦，會期自民國九十年九月十六日至廿一日，議程如下：

- 九月十六日

  10:00 ~ 16:00 國際飛安調查員協會執委會（Executive Council）會議，會中由本會失事調查組組長周光燦報告 ISASI 2002 年會籌備情況。

  ※執行委員會會議議程詳如附錄一

- 九月十七日

訓練課程

09:00 ~ 12:00 專業及個人溝通技巧

- 教師:Thomas Fakoussa,
  Awareness Communications, Inc, Germany

13:30 ~ 16:30 如何與媒體工作

- 教師:Garth Rowan,
  ALLAIRE, ROWAN COMMUNICATIONS COUNSEL

- 九月十八日

  08:30 開幕式

  08:35 會務報告

Mr. Frank Del Gandio, President, ISASI

國際飛安調查員協會（ISASI）會長

08:45 ~ 09:10 演講:

Mr. Charlie Simpson,
Member of Transportation Safety Board

加拿大運輸安全委員會 委員

專題報告

09:10 瑞士航空公司 SWR283 班機失事人為因素調查＊

Mr. Timothy Crouch, ALPA, Swiss Air

09:35 航空器失事調查與刑事偵查

Mr. Dick Wood, Retired, NTSB, USA

10:30 進場、降落與控制飛航撞地失事預防

Mr. Jim Burin,
Flight Safety Foundation, USA

10:55 亂流造成航空器失事預防

Mr. Bob Mathews,
Accident Investigation Office, FAA, USA

11:20 航空燃油污染調查

Mr. Mike Watson,
Australian Transportation Safety Bureau

11:45 討論

13:15 新加坡航空公司 SQ006 班機失事 - 飛航管制調查

周光燦,行政院飛航安全委員會失事調查組組長

13:40 管制員如何處理航空器緊急情況

Dr. Sue Baker / Mr. Ian Weston, CAA, UK

13:45 ~ 17:00 地區分組討論

- □ 加拿大分組
- □ 歐洲分組
- □ 紐西蘭分組
- □ 美國分組
- □ 國際分組

● 九月十九日

專題報告

08:30 海灣航空公司 GF072 班機失事調查

Capt. Mohamed Aziz, Mid East Airlines, Lebanon

08:55 新加坡航空公司 SQ006 班機失事調查心得

Dr. Kay Yong, Aviation Safety Council, Taiwan, ROC

戎　凱,行政院飛航安全委員會 執行長（因故未能出席,由本會失事調查組組長周光燦代為報告）

09:20 埃及航空公司 IA990 班機失事調查＊

Mr. Capt. Shaler & Capt. Meseeri, Egypt Airlines

10:30 瑞士航空公司 SWR111 班機失事調查＊

Mr. Vic Gerden, Transportation Safety Board, Canada
Mr. Jim Foot, Transportation Safety Board, Canada
Mr. Daniel Verreault, Transportation Safety Board, Canada

11:45 討論

13:30 客艙安全專題報告

Ms. Nora Marshall,
National Transportation Safety Board, USA
Mr. Thomas Waldeck, USA
Mr. Mike Cavenaugh, USA

15:15 ~ 17:00 工作小組討論

- 教育訓練小組
- 飛航管制小組
- 客艙安全小組
- 普通航空小組
- 商業航空小組

● 九月二十日

專題報告

08:30 人為因素調查方法之探討

Mr. Randall Mumaw,
Boeing Commercial Airplane Company, USA

08:45 鳥擊案件 – 迷思與真相

Mr. Al Weaver, Retired P & W, USA

09:20 巴黎戴高樂機場跑道撞機失事調查

Mr. Pierre Jouniaux & Franck Giraud, BEA, France

09:45 討論

10:30 航空器空中相撞調查技術

Mr. Keith McGuire,
National Transportation Safety Board, USA

10:55 航空器儀表顯示錯誤與失事

Mr. Simon Lie, ASI,
Boeing Commercial Airplane Company, USA

11:20 航空器失事生還因素之改善情形

Mr. John Patrakis, USA

11:45 討論

13:30 駕駛艙影像記錄爭議與解決

Mr. Thomas Fakoussa,
Awareness Communications, Inc, Germany

13:55 加拿大失事調查待改善之處＊

Mr. John Pottinger, Text Pilot, Canada

14:20 討論

15:30 國際飛安調查員協會 2002 年會籌備工作小組報告

周光燦,行政院飛航安全委員會失事調查組組長

16:00 閉幕典禮

註：＊符號為該篇論文未刊載於年會手冊。

參、心得

由於年會前美國發生有史以來最嚴重之恐怖份子攻擊事件，導致美加兩國暫停民航班機起降，空域及機場重新開放後，航班調度一度混亂，造成原本應有四百餘人參加之年會僅有二百人能趕到，主辦單位曾考量延期舉行，但亦不能確定在今年內能順利完成，故仍然按期舉行。雖然會議遭遇如此重大困難，整體而言尚能維持一定水準，遺憾是與會人數銳減使得訓練及交流之效果不如預期。

因為年會在維多利亞國際會議中心舉辦，專業之會場空間設計優良，視聽設備完善，無論是全體代表大會或分組討論都能滿足需要。而會場外之展示及代表交流聯誼空間亦頗為寬闊與方便。

今年主辦單位刻意不印製年會手冊（Proceedings），代之以光碟片（CD-ROM）。此舉非但減輕與會人士之負擔，更便利使用者閱聽多媒體簡報，相關論文及資料之引用與交流更為方便。

本次年會主辦單位係加拿大飛安調查員協會（CSASI），從三年前開始爭取主辦，其間投注之人力、物力與時間十分龐大，尤其是尋求贊助廠商（共廿一個）方面。所有與會代表在會議期間之餐飲非但免費，而且另外贈予手提袋及加國特產，使來賓印象深刻。

相較於去年年會，今年主辦單位有多項改進，特別是網上註冊（online registration）手續簡便，無論對主辦單位或是參加會議人士

都是一項德政。

本屆年會之另一特色為有關航空器失事調查之論文較去年為多，包括瑞士航空公司 SW111、新加坡航空公司 SQ006、海灣航空公司 GF072、埃及航空公司 IA990 等。另外有跑道入侵（Runway Incursion）、客艙安全及亂流造成之航空器失事等論文，涵蓋領域甚廣，極具參考價值。

本會成立伊始即加入 ISASI 為團體會員，以往均以參與及聯繫為主。但在本屆年會中本會提出兩篇論文，將新航失事調查相關之經驗、心得及困難與國際同業分享。效果超過預期，獲得與會人士一致肯定，咸認本會在短暫期間內所建立之調查能量以及專業表現出色。不少國際同業於休息時間向本會代表致意，亦對本會之運作表示極大興趣。

本會代表曾於年會前之執委會會議報告下屆年會籌備進度，順便觀察執委會運作情形。目前 ISASI 積極推動飛安教育推廣計畫（Reachout Program），希望藉以提昇記錄不佳地區之飛安水準。今年五月曾在捷克布拉格市舉辦，有超過一百位東歐國家之飛安及調查人員參與，成績斐然。未來重點在拉丁美洲、非洲及中國大陸。

至於在會場外之展覽，同樣受到九一一事件影響僅有八家廠商設有攤位，包括：航空器製造廠、教育訓練、調查軟體、風險評估等。

其中教育訓練分別來自南加大（University of Southern California - USC）及南加安全學院（Southern California Safety Institute - SCSI)。調查軟體則係為加拿大運輸安全委員會開發模擬飛航動畫系統（RAPS）之廠商。已將上述兩類簡介資料攜回供同仁參考。

肆、建議

為順利辦理 ISASI2002 年會，本會允宜爭取寬列下年度公務預算以支應會議所需費用，初步估計辦理會議約需新台幣貳佰伍拾萬元。會議前之註冊、場地、餐飲及旅遊等之規劃工作非但需要專業人員之協助，更需有額外之人力承擔此項工作。本會人力相當精簡，若在籌備期間發生重大飛航事故，有限人力勢必投注於調查作業，而年會之籌備又不容許失敗，特此建議另外編列委辦預算，以便委外代辦。

參加國際專業組織活動目的在觀摩學習專業新知，建立聯繫管道以及分享資料與經驗。今年本會首度在 ISASI 發表論文頗受好評。建議本會及國內民航同仁未來能踴躍發表論文，除與國際同業分享資訊外，並能提昇國際形象與地位。

建請本會及國內民航同仁籌組 ISASI 亞太分會，以加強地區協調聯繫，進而提昇本區飛安水準。另外亦應積極爭取擔任 ISASI 執行委員會委員，將我國專業技術與經驗貢獻國際社會。

伍、附　　錄

一、 航空器失事調查與刑事偵查

The Criminalization of Aircraft Accidents
By Richard H. Wood,
Mr. Wood is an aviation safety consultant with over 35 years experience in aircraft accident investigation. He is a pilot, a Certified Safety Professional, and a retired Professor of Safety Science at the University of Southern California. He is co-author of Aircraft Accident Investigation, the current textbook on that subject.

二、 進場、降落與控制飛航撞地失事預防

Learning the Lessons of Approach and Landing and CFIT Accidents, and Using the Lessons to Prevent Others
By Jim Burin, Director of Technical Programs
Flight Safety Foundation

三、 亂流造成之航空器失事與可能解決方案

TURBULENCE ACCIDENTS AMONG U.S. AIR CARRIERS:
THEIR SCALE AND POSSIBLE SOLUTIONS
By Robert Matthews, Ph.D.
Office of Accident Investigation
Federal Aviation Administration, USA

四、 航空燃油污染調查

Fuel's Fuel, whether it's from Afghanistan or Australia.
By Mike Watson, Australian Transportation Safety Bureau

五、 航空公司面臨之挑戰、選擇、結果

The Airline Industry - Challenges – Choices – Consequences
By James L. Cole, Jr. (MO4544) - Air Transport Association of America
During a thirty-year career in the U.S. Air Force, "Jack" Cole logged 2,000 hours in DC-3's and also has extensive heavy jet instructor and check pilot time. As Commander of the 89th Airlıft Wing, he directed and

operated VIP air transportation for the U.S. President and senior government officials. He also directed the entire safety program for the U.S. Air Force, managing all flight, weapons, explosives, and ground safety. Cole is currently the Senior Director, Safety, for the Air Transport Association of America.

六、 奥運會期間之空中交通管理

AIR TRAFFIC MANAGEMENT IN AN OLYMPIC CITY
By John Guselli MO 3675 - JCG Aviation Services Pty. Limited.
John Guselli was employed by Airservices Australia and its civil aviation predecessor organizations between 1972 and 2000. He was licensed as an Air Traffic Controller in 1974 and served in a wide variety of roles including that of Airport Manager, ATS Center Manager, Operational Training Manager, and ATS Safety Manager. In 1998 he was appointed to the position of National Olympics Manager for Airservices Australia where he successfully coordinated all aviation elements of the Sydney 2000 Olympic Games. He is currently Vice-Chairman of the ISASI ATS Working Group.

七、 新加坡航空公司 SQ006 班機失事 - 飛航管制調查

Singapore Airlines Flight SQ006 Accident Investigation
By Kuang-Tsang Chou, Investigator, Aviation Safety Council, Taiwan, ROC. Before joining the Council, Mr. Chou had been working with Civil Aeronautics Administration, Taiwan for over 27 years. His last position at CAA was the Chief of Chiang Kai-Shek Approach.
周光燦,行政院飛航安全委員會失事調查組組長,中華民國台灣

八、 管制員如何處理航空器緊急情況

"MAYDAY, MAYDAY, MAYDAY"
A Joint Paper by Dr Sue Baker, Head of Human Factors and By Mr Ian Weston, Head of Safety Investigation and Data Department, United Kingdom Civil Aviation Authority

九、 海灣航空公司 GF072 班機失事調查

FLIGHT GF072 ACCIDENT AIRBUS A320 - 23 AUG. 2000 BAHRAIN
By Salah Mudara,
Manager Flight Safety - Gulf Air
Salah Mudara has been with Gulf Air for 25 years at the company headquarters in Bahrain. Served as an Engineer in various positions in the Technical Division before being appointed Manager Flight Safety in 1995.

十、 新加坡航空公司 SQ006 班機失事調查心得

By Dr. Kay Yong, Aviation Safety Council, Taiwan, ROC
戎　凱,行政院飛航安全委員會 執行長, 中華民國台灣

十一、 客艙安全專題報告

1. Recent NTSB Cabin Safety Investigations
   By Nora C. Marshall, National Transportation Safety Board
2. Unified System Safety Model For Global Flight Operations
   By Thomas A. Waldeck (MO4599), Flight Operations System Safety Analyst
   Waldeck has over 40 years of experience in aviation, most of which was with The Boeing Company. Before retiring in 1995 he worked in flight test, safety, and aerodynamics. During that time he participated in each stage of an airplane's lifecycle, from conceptual design on through to supporting flight operations Since retiring he has been constructing a safety model that clearly presents some of the key lessons learned during the first century of flight that must be passed on to the next.

十二、 人為因素調查方法之探討

Guessing Why Before Determining What:
Hypothesis Generation in Data Gathering for Human Factors Investigations
By Randall J. Mumaw, Ph.D.
Human Factors Specialist - Boeing Commercial Airplanes, Seattle, USA
Randall J. Mumaw is a cognitive psychologist who supports flight deck human factors for Boeing Commercial Airplanes. His areas of interest are system design and evaluation, human error, decision making,

training, and cultural influences on safety.

十三、 鳥擊案件 — 迷思與真相

Bird Strikes - Myths and Realities

By Al Weaver designed and conducted the first bird ingestion tests into commercial jet engines in the early 60's in support of demonstration criteria for the FAA. He was instrumental in supporting the FAA data collection efforts to define the bird ingestion hazard and the response of the engines to this hazard since 1980. Mr. Weaver was the industry chairperson for recommending changes to the design and testing standards for these engines culminating with the recommendations to the FAA and JAA for updating these standards worldwide.

Al is retired from Pratt & Whitney and currently teaches gas turbine accident investigation techniques at Southern California Safety Institute.

十四、 巴黎戴高樂機場跑道撞機失事調查

Collision between an MD83 & a Shorts 330 at Roissy Charles de Gaulle Airport On May 25th, 2000

By Mr. Pierre Jouniaux & Franck Giraud, BEA, France

十五、 航空器空中相撞調查技術

Using Physical Evidence From A Mid- Air Collision

By Keith McGuire, M02416, Northwest Regional Director, NTSB

The views expressed in this paper are those of the author and not necessarily the views of the NTSB.

Keith McGuire is the Director of the National Transportation Safety Board's Northwest Regional Office. A former pilot with the US Air Force, Keith has a B.A. in Physics, an M.A. in Counseling Psychology and has completed the Senior Executive Fellows Program at Harvard University.

十六、 航空器儀表顯示錯誤與失事

Erroneous Instruments and Aircraft Accidents

By Simon Lie (AO4462), Air Safety Investigator - Boeing Commercial

Airplanes

Simon Lie has been with Boeing for 12 years. Before becoming an Air Safety Investigator, he worked on gust and buffet load analysis, central maintenance computer design and as a flight line engineer for 737, 747, 757, 767, and 777 airplanes. He received his bachelor's and master's degrees in aeronautical engineering from the Massachusetts Institute of Technology.

十七、 航空器失事生還因素之改善情形

20 YEARS OF CRASHWORTHINESS IMPROVEMENTS
By John J. Petrakis, Federal Aviation Administration

十八、 駕駛艙影像記錄爭議與解決

What improvement do we get from cockpit video?
By Awad Thomas Fakoussa,
Awad Thomas Fakoussa, born 1948 in Port Said, Egypt. Grew up in Germany and became a pilot. He flew as flight instructor in professional pilot schools and also as captain on B 737's apart from studying psychology and running seminars about the art of learning, teaching, CRM, management training etc. Since 1994 facilitated the new art of Personal Resource Management – PRM

十九、國際飛安調查員協會 2002 年會籌備工作小組報告

ISASI 2002 PRESENTATION
By Kuang-Tsang Chou, Investigator, Aviation Safety Council, Taiwan, ROC. 周光燦,行政院飛航安全委員會失事調查組組長,中華民國台灣

附錄一

國際飛安調查員協會(ISASI)執行委員會會議議程

ISASI International Council Meeting

September 16, 2001
Victoria, British Columbia, Canada
Meeting Agenda

1. Call to Order – Frank Del Gandio, President
2. Approval of Minutes of Previous Meeting – April 27 ~ 28, 2001, Herndon, Virginia, USA
3. Report of Action Items from April 27 ~ 28, 2001 Meeting
   - Action Sept.1999 – Reactivation of Chapters. Specific concern was the inactivity of the Los Angeles Chapter. Curt Lewis will contact some of the key members in the Los Angeles area in an attempt to determine what is needed in order to initiate some activity.
   - Action April 2001 – Development of a reachout seminar Guidelines and Manual. Jim Stewart with assistance from Kevin Darcy, as needed, agrees to develop seminar guidelines and a manual for future Reachout Seminars.
4. Report of Council Executives:
   - President - Frank Del Gandio
   - Vice President – Paul Mayers
   - Treasurer – Tom McCarthy
   - Secretary – Keith Hagy
   - Executive Administrator – Richard Stone
5. Report of National Societies/Councilors:
   - ASASI – Lindsay Naylor
   - CSASI – Barbara Dunn
   - ESASI – Max Sait-Germain
   - NSASI – Ron Chippindale
   - USSASI – Curt Lewis
   - International – Caj Frostell
6. Reports received from Society Chapters
7. Report of ISASI Forum Editor – Marty Martinez
8. Reports of the ISASI Committees
   - Audi – Hynes
   - Bylaws – Mercer

- Technical Library – Benner
- Nominating – Kerfoot
- Seminar – Darcy
- Awards – Pocock
- Membership – McCarthy
- Board of Fellows – Hall
- Code of Ethics and Coduct – Combs
- Reachout – Jim Stewart

9. Reports from Working Groups
    - Air Traffic Services – Gaines
    - Human Factors /Aircraft maintenance – Crotty
    - Investigator Training & Education – Doub
    - Corporate Affairs – Purvis
    - Positions – Smart
    - Cabin Safety – Marshall
    - Human Factors – Walker/Maurino
    - Flight Recorder – Poole
    - Government Air Safety Investigators - Cavenagh
10. 2002 Taipei Seminar – Kuang-Tsang (KF) Chou
11. 2003 Washington D.C. Seminar – Nora Marshall
12. Unfinished Business
    - 99-2: ISASI Positions Document – Smart
      A review of the ISASI Positions document will be a standing agenda item for every council meeting.
    - 99-5: Reactivation of Chapters – Lewis
      Continued from the April 2001 meeting.
    - 99-9: ISASI Website Status Update – Stephens
      This item is a standing agenda item pending continued development and enhancement of the ISASI wesite.
13. New Business
14. Adjournment

附錄二

航空器失事調查與刑事偵查

The Criminalization of Aircraft Accidents

By
Richard H. Wood,

The Criminalization of Aircraft Accidents

Richard H. Wood, LM0598

Mr. Wood is an aviation safety consultant with over 35 years experience in aircraft accident investigation. He is a pilot, a Certified Safety Professional, and a retired Professor of Safety Science at the University of Southern California. He is co-author of Aircraft Accident Investigation, *the current textbook on that subject.*

Introduction

There has always been a gray area in the aircraft accident investigation business. When does an accident stop being an accident and start to become a crime? As I will point out later, that depends somewhat on your culture and what the word "accident" means to you. It also depends on your goals. What do you expect to result from the investigation? Do you seek the satisfaction of having administered punishment to someone or would you prefer to prevent future accidents? I think I already know the answer to that. If you didn't believe that the primary purpose of investigation was prevention, you wouldn't be here at all. You can't punish an accident and expect to prevent anything. (1) It doesn't work.

This disagreement, if you like, between preventers and punishers has always been with us, but in the past few years it seems to have gotten out of control. Even the National Transportation Safety Board has noticed it. Jim Hall, the former chairman of the NTSB stated over a year ago that, "We have seen a slow but steady and growing presence of the law enforcement authorities in our investigations." (2) That's a fairly mild statement and it applies not only to the United States but to many countries of the world.

Item: Following the Learjet accident in which golfer Payne Stewart was killed, Fifty FBI agents raided the charter company that owned the aircraft and impounded 160 boxes of flight logs and maintenance records which essentially put the company out of business. They couldn't operate without the records. (3)

Item: Following the accident involving Alaska Airlines Flight 261, FBI agents and government attorneys attempted to interview Alaska employees in apparent violation of a California law barring lawyers and government investigators from directly contacting people represented by counsel.(4)

Item: In Paris following the Concorde accident, a panel was established almost immediately for the purpose of determining the need for criminal prosecution.(5). Whether this impeded the investigation of the accident is not known.

Item: Following the Singapore Airlines accident in Taipei, the cockpit crew was detained by prosecutors in Taiwan. They were not permitted to leave the country for nearly two months and then only after a promise by Singapore that they would return if required. (6)

Item: In the United States, in accidents involving all transportation modes, it has become common for witnesses and company officials to refuse to cooperate with the National Transportation Safety Board. Since they are aware of the possibility of criminal sanctions, they assert their Fifth Amendment privilege against self-incrimination. (7)

The Problem

Deep in our hearts, most of us really don't believe that accidents are accidents. Let me give you a few definitions of an accident. (8) ICAO just calls it an occurrence. Safety professionals refer to it as an unplanned, unforeseen and unsought event. Others refer to it as an event occurring by chance or arising from unknown causes. The current dictionary definition is a happening that is not expected, foreseen or intended. The common thread among all those definitions is that an accident is not a deliberate act and it is not a crime as defined by our laws. That's the part we don't really believe. If the event results in injury or damage, our instinctive reaction is that someone is at fault and that person must be identified and punished.

In some parts of the world, the words "accident" or "safety" or "prevention" do not translate well. Injuries or damage are crimes and there is no such thing as an accidental crime. Dr. Kay Yong is the Managing Director of the newly formed Aviation Safety Council of Taiwan. In a recent speech, he stated that prior to the formation of the Aviation Safety Council, "The sole purpose of aircraft accident investigation was to find the guilty party; not to improve safety." (9)

Upon hearing that, those of us from the United States look smug and claim to be above that sort of thing--but we aren't. If our official government investigation does not satisfy our urge for punishment, there are other branches of our government, both federal and state, who are fully prepared to prosecute someone for something. If that doesn't work, we will seek some other form of redress. This is called litigation and we are the world's leader in that field.

The problem with punishment is that we are almost always dealing with errors in judgement or technique. Deliberately violating a law is a criminal act regardless of the outcome and punishment may be appropriate if it prevents future violations of that law. Making a mistake while trying to comply with the law is not a crime and punishing that mistake isn't going to prevent anyone from making that same mistake in the future.

In ICAO Annex 13, which we all know and love, the most useless statement in there is the one describing the objective of the investigation. I'll read it to you in case you have forgotten it.

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability. (10)

Although the NTSB does not apportion blame or liability in its reports, our news media will always correct that oversight for them. They will establish blame based on the NTSB report. Why? Because we demand blame. That's why.

Another problem with punishing an accident is that the act of punishing someone makes it difficult to take any other preventive action. Let me return to the Singapore Airlines accident in Taiwan for a moment. At this writing, Dr. Yong's report on that accident is not complete, so what I'm about to say is somewhat speculative. The crew attempted to take off on a closed runway. We know that and we can agree, I think, that a bad mistake was made. So far, I haven't heard anyone claim it was deliberate. Based on what I've read about the accident, though, it appears that the runway was not marked as closed, its lights were on, and the only taxi lines, if followed, led to the closed runway. If that's true, did those factors contribute to the crew's mistake? If we punish the crew and then correct the airport deficiencies, won't that imply that perhaps punishing the crew was not the correct preventive action? Yes, it will. In the safety business, it's almost a given that if a person is punished for making a mistake, that's the end of it. Nothing else will be done.

The Solutions

First, we must choose between the long range benefits of prevention and the short range satisfaction of punishment. Most of us attending this seminar have already made that choice. That does not necessarily mean that our governments have made the same choice.

If we intend to stay on the prevention side of that argument, we need to provide our investigators with the ability to grant confidentiality if that's what it takes to get the information they need.

The second most ignored part of ICAO Annex 13 is the one on disclosure of records. (11) That's too long to read to you, but essentially ICAO provides a list of records that should not be made available for any purpose other than accident or incident investigation. Included on the list are all statements taken from persons by the investigation authorities in the course of their investigation. Few countries follow that and even the United States has filed a "Notice of Difference" with ICAO stating that it is not possible to do that under existing United States laws. That's True. Neither the NTSB nor the FAA can withhold any statement given them. That's part of the problem right there. If the person who knows what happened in the accident chooses not to explain it, there is no power short of torture that will make him explain it. In the United States, whatever statement he gives the NTSB in any form becomes a public document and can be used against him in any other action. Knowing that, a pilot involved in an aircraft accident in the United States would be well advised to bring a lawyer to the interrogation and listen closely to his lawyer's advice on answering questions. Few people are going to answer questions if the answers can be released and used against them in some other action. You wouldn't do that and neither would I.

Back in the mid 70s, I was subpoenaed as a witness in federal court in Los Angeles. We were defending the Air Force's right to withhold certain documents from an aircraft accident report. These included witness statements because they had been obtained under a promise that they would not be released or used for purposes other than accident prevention. The witness ahead of me was my boss, General Chuck Yeager, the first man to break the sound barrier. The case was on appeal and it was tried before a judge; no jury. I don't have a record of Chuck Yeager's exact words, but they are etched in my mind as though they happened yesterday.

"Judge," he said, "here's the situation. In my flying career, I've had four or five accidents. A couple of them were my fault. I screwed up and I knew it and I was the only one that knew it. If the accident investigation board had not promised me that my statement would not be released, there is no way in hell I'd have told them what happened and they would never have figured it out for themselves." (12) We won.

The United States military has always granted that type of immunity to witnesses involved in aircraft accidents. Until 1984, that had been regularly challenged because the military's right to do that was not based on any statutory law. In 1984, a challenge went to the United States Supreme Court and the Court upheld the military's right to withhold statements obtained under assertions of confidentiality. The Court vote was nine to nothing which is a perfect score. It doesn't get any stronger than that. (13)

Wouldn't or couldn't the same logic be applied to the NTSB? Maybe. Under our existing laws, there is plenty of precedent for granting some degree of immunity if it is necessary to obtain information. That is not a new idea. That would solve the problem of people refusing to cooperate with the NTSB.

Suppose we do that. Then the NTSB encounters another problem because they must actually protect the information gained under a promise of confidentiality. I can think of a lot of groups that would be seriously disturbed at the idea of the NTSB withholding information. I recommend the military's standard response. "Here are the names of the witnesses who gave us information. Go talk to them yourself."

So that's the first part of the solution. Grant the NTSB the right to keep information in confidence if that is necessary to obtain it in the first place and then keep the information in confidence. The second part of the solution is a little sticky.

Because we believe that prevention, in the long run, is more important than punishment, we allow our investigative organizations to be in charge of the initial investigation and we give them considerable latitude in how they do that. We cannot, however, ignore the fact that there are other groups who have a legitimate right to also investigate the accident for other purposes. These include law enforcement agencies, insurance companies and litigants. In the process of conducting the primary investigation, if we hinder, obstruct or defeat any subsequent investigation, we are asking for trouble. Another agency, or even a single lawyer, is likely to be offended and can bring the NTSB's investigation to an abrupt halt. That has happened.

Is obstruction of future investigations a problem? Yes it is. Many of us in this room have had the experience of trying to reconstruct an accident after the NTSB was finished with it. The documentation of the accident scene, including descriptions, diagrams and photographs, is terrible. The wreckage no longer resembles that found at the scene and it is frequently incomplete. The missing parts are usually the good ones. They have found new life as a paperweight on someone's desk or possibly an exhibit in the lab. If the NTSB wants to enjoy investigative primacy, it must change its tactics. I can think of only two ways to do this and neither are likely to be popular.

First, the NTSB could learn how to document a scene and preserve evidence. They do not know how to do this now and show little interest in learning. One might ask what sort of formal training NTSB investigators have had in any form of investigation. We might say that , as a group, they are well-practiced which is not the same thing as well-trained.

If that isn't acceptable, then the NTSB must give up the present practice of denying access to those who can document a scene, already know how to preserve evidence, and have a legitimate right to gather facts in support of a future investigation. That might be the easier of the two solutions and might even be helpful.

Those are the only two choices I can think of. Either learn how to preserve the evidence or allow others to do it for you.

Summary

The criminalization of aircraft accidents is taking us down the wrong road. If we believe that the primary purpose of aircraft accident investigation is to prevent future accidents, then we must provide our investigators with the tools to obtain the information they need. If this involves keeping the information obtained in confidence, then it must be kept in confidence.

We cannot ignore the rights of others to also investigate an accident. We cannot allow our investigators to act in a manner that would violate those rights or inhibit future investigations.

Notes

1. Wood, Richard H., *Can you Punish an Accident?* ISASI Forum, 1981.
2. New York Times, April 17, 2000.
3. Aviation Maintenance, June, 2000.
4. Seattle Times, July 23, 2000.
5. Aviation Week & Space Technology, August 14, 2000
6. The Australian, December 23, 2000.
7. Kenneth P. Quinn, former FAA Chief Counsel, Commentary in Air & Space, December 2000/January 2001.
8. Among the 20 or so safety management textbooks in the author's library, there is very little difference among them in how the term "accident" should be defined.

9. Opening Speech delivered to the 18th Annual Aircraft Cabin Safety Symposium, February 13, 2001.
10. ICAO Annex 13, Aircraft Accident and Incident Investigation, 8th ed., Section 3.1.
11. ICAO Annex 13, Aircraft Accident and Incident Investigation, 8th ed., Section 5.12.
12. Theriault v. United States, 395 F.Supp. 637 (1975).
13. United States v. Weber Aircraft Corp., 465 U.S. 792, 79 L. Ed.2d 814, 104 S. Ct. 1488 (1984).

附錄三

進場、降落與控制飛航撞地失事預防

Learning the Lessons

of

Approach and Landing and CFIT Accidents,

and

Using the Lessons to Prevent Others

By

Jim Burin,

Director of Technical Programs

Flight Safety Foundation

Learning the Lessons of Approach and Landing and CFIT Accidents, and Using the Lessons to Prevent Others

Jim Burin
Director of Technical Programs
Flight Safety Foundation

Jim Burin has 34 years of aviation experience and 26 years of experience in the aviation safety field. His work in aviation safety activities includes controlled-flight-into-terrain, human factors, safety program organization, accident investigation, operations, administration, education, and organizational influences on safety, operations, administration, and education. He is a retired Navy captain, having commanded an attack squadron and a carrier air wing Prior to joining the Flight Safety Foundation, he was the director of the School of Aviation Safety in Monterey, California.

The Flight Safety Foundation recently completed a nine-year international effort to address the challenges of controlled flight into terrain (CFIT) and approach and landing accidents (ALA). This paper will discuss some of the history of this effort and the current status of the project. It will also show how some of the history has been used to improve the interventions currently being implemented.

The first question to ask is "why CFIT and ALA?" Why not study runway incursions or uncontained engine failures? Well, the chart in figure 1 shows why this effort was initiated. CFIT is the leading killer in commercial aviation, and ALA is the most common type of accident. Everyone knew there were problems in these areas; there was a lot of qualitative information to confirm that. However, there was no study, nothing quantitative to base any interventions on. The Foundation initially looked at addressing both CFIT and ALA simultaneously, but we quickly realized that trying to address both areas at once was just too big a task. Since CFIT was the leading cause of fatalities, we chose to address it first. In 1996, after three years of work by over 150 international aviation experts, recommendations concerning CFIT were released. In addition to recommendations, there were also products. These included the CFIT training aid, which consisted of a CD, a video, and 2 volumes of information on CFIT. There was also the CFIT checklist and multiple publications addressing CFIT. We felt good about the CFIT effort. We sent out thousands of the training aids, we won some awards, and the CFIT rate started to come down (see figure 2). Then came 1998. Things did not go well CFIT wise in 1998. There were 7 commercial jet CFIT accidents, a real shock and setback to the CFIT effort. As you can see from figure 2, there was only one commercial jet CFIT in 1999. However, of the 28 commercial turboprop accidents in 1999, 14 were CFIT, accounting for 80 percent of their fatalities for the year. In fact, despite a focus on training, efforts to increase awareness, and some new and exciting technologies, there have been an average of 3 commercial jet CFIT accidents a year for the last 20 years. As shown in figure 2, last year we had 3 CFIT accidents. That is not progress.

So what happened to the CFIT plan? That is a question that was often asked. In fact, there were several answers. First, the size of the CFIT training aid was intimidating – a CD, a video, and 2 volumes of information. Some organizations, like British Airways, easily integrated the information into their training program. However, for many aviation organizations the assets were not available to enable them to effectively utilize all the information in the training aid. In addition, the training aid was not user friendly. There was a lot of data and information there, but it was not in a readily usable format. Also, many of the training aids never got to the intended users. We don't know where many are (probably on a library shelf, or still in the box). Finally, there was no feedback loop set up. The training aid was just sent out around the world with the hope that it would be used.

As all this was going on, the approach and landing accident reduction (ALAR) task force was already underway. It included much of the CFIT work. This study was based on 287 fatal approach and landing accidents that occurred between 1980 and 1996. This included all jet and turboprop aircraft with a maximum take off weight over 12,500 pounds. The top 5 ALA types from this study were: CFIT (including landing short); Loss of Control; Landing Overrun; Runway Excursion; and Non-stabilized Approaches. In December of 1998 the ALAR Task Force report titled "Killers in Aviation" was released. This report has become the reference book on CFIT and ALA. Over 40,000 copies of this 278-page report have been downloaded from the FSF web site. The report has been used as a reference by NTSB (who reprinted an entire section in the KAL/Guam accident report), by TSB Canada, and by The Netherlands Transportation Safety Board, to name just a few. It replaced a lot of qualitative ideas with quantitative facts. Figure 3 lists the eight basic recommendations of the ALAR task force.

So the CFIT task force was complete, but the success of its recommendations and in implementing the training aid was questionable, and the ALAR report and recommendations were complete – now what? To answer that question a special joint meeting of the Flight Safety Foundation's three advisory committees (International, European, and Corporate) was held. The result was that a new group was formed from the nucleus of the CFIT and ALAR task forces. This group was known as the CFIT and ALAR Action Group (CAAG). We wanted the CAAG to utilize the lessons learned from the CFIT experience to more effectively implement the CFIT and ALAR recommendations. The goals of the CAAG are shown in figure 4. First was to conduct a regional implementation program on a global basis. One of the keys to the regional implementation plan the CAAG devised was the creation of the position of Regional Team Leader (RTL). This was to be an individual or organization that was a native speaker of the predominant language of the region, someone active in the region's aviation community, and someone who had contacts and creditability within the region. We wanted the RTL to run the implementation of the CFIT and ALAR interventions for their region. The RTL would know who to go to, and what had to be done to make the plan work for their region. That was our vision, to create a training aid that would assist in implementing the interventions of the CFIT/ALAR effort and that would address commercial, cargo, and corporate operators as well as ATC, regulators and airports. These goals would enable us to implement our CFIT and ALAR interventions globally on a regional basis in a focused, user friendly product.

The culmination of the CFIT/ALAR effort is the ALAR Tool Kit. This CD consolidates the data, products, findings, conclusions, and recommendations of nine years of work by almost 300 aviation experts. The tool kit contains many different elements, each designed to help prevent CFIT and ALA accidents. One of the primary elements of the tool kit is the briefing notes. There are 34 of these 3-7 page documents, each on a specific topic. Some sample briefing note topics include; SOP's, Managing Interruptions/distractions, Being prepared for Go-around, and Energy Management During Approach. A complete list of the briefing note topics is given in figure 5. Each briefing note has statistical data to support it, a discussion section, a summary, and references. The references are not only listed, but by selecting a reference you get the entire reference document. There are over 2,500 pages of reference material in the tool kit. In addition to the briefing notes, the tool kit also contains CFIT information (the CFIT check list, a CFIT brief, and a CFIT video) and ALA information (several briefings, the ALAR risk assessment tool, and a video). All the briefings contained in the tool kit are power point briefings with speakers notes included. There are also ALAR posters, an SOP template, and the entire "Killers in Aviation" publication contained in the tool kit. Figure 6 gives a complete listing of the contents of the tool kit. The tool kit utilizes lessons learned from the CFIT effort in a focused, user-friendly product that is self-contained and ready to use.

Of course the key to getting full benefit from the tool kit is the regional implementation plan and the Regional Team Leader. The CAAG will support the designated RTL with workshops or any other requirements they may have. In addition, ICAO, IATA, IFALPA, and IFATCA have all pledged their support in assisting the RTL's in implementing the interventions on a regional basis. The first regional effort was started in December 2000 in Latin America. The regional team leader is the Pan American Aviation Safety Team (PAAST). They have designated action team leaders and are well on their way to implementing their plan, which also includes a method to measure the success of their effort. The next region will be the Asia/Pacific region, which will kick off its program in September. After that the regional effort will move to the Middle East and then Africa. Of course other regions are free to take the tool kit and start their own programs at any time. Iceland has done just that, and several European organizations are discussing ways to coordinate their implementation. We know and expect each region will be somewhat different in its approach and planning for implementation, but that is the strength of the regional approach. Each region can tailor its program to ensure implementation in their region is done most efficiently.

The tool kit is available now. It is a comprehensive, user friendly means of trying to reduce the risk of the primary challenges to safety in aviation by disseminating, educating, and communicating the CFIT and ALA recommendations on a global level to hopefully reduce the risk of these killers in aviation.

附錄四

亂流造成航空器失事與可能解決方案

TURBULENCE ACCIDENTS

AMONG

U.S. AIR CARRIERS:

THEIR SCALE AND POSSIBLE SOLUTIONS

By

Robert Matthews, Ph.D.

Office of Accident Investigation

Federal Aviation Administration, USA

TURBULENCE ACCIDENTS AMONG U.S. AIR CARRIERS: THEIR SCALE AND POSSIBLE SOLUTIONS

Robert Matthews, Ph.D.
Office of Accident Investigation
Federal Aviation Administration, USA

From 1981 through 2000, U.S. air carriers were involved in 156 turbulence accidents (this excludes wake turbulence. Though turbulence accounted for just 3 of the total 2,944 fatalities in airline operations over the 20-year study period, turbulence accounted for more serious injuries than any other accident type (218 of 802 serious injuries over 20 years, or 27.2 percent), plus 615 minor injuries. Incidents investigated by the National Transportation Safety Board (NTSB)or by the Federal Aviation Administration (FAA) add an average of 50 more minor injuries per year.

Both the number and rate of turbulence accidents have increased sharply since 1995 and are likely to continue at or above their currently high rates. This paper reviews trends and characteristics of turbulence accidents and incidents, then evaluates options for reducing their frequency.

To reduce turbulence accidents, this paper recommends focusing on inexpensive efforts to avoid turbulence and to ensure that passengers and flight attendants are seated and properly secured during turbulence. More complex technological solutions will be hard pressed to meet practical operational requirements or to compete for finite resources with efforts to avoid other, more severe types of accidents.

PART ONE: GENERAL TRENDS AND CHARACTERISTICS

Exhibit 1 shows the annual number of turbulence accidents and associated serious injuries among U.S. air carriers from 1981 through 2000. Exhibit 2 shows the turbulence accident rate. Despite some annual variation, the figures show that the number of accidents and injuries remained fairly stable from 1981 through 1994, averaging 5.5 accidents and 8.5 serious injuries per year, including 1 fatal injury in 1987 and 1 in 1990. While the number of turbulence accidents remained fairly stable in those years, aircraft operations increased. As a result, the rate for turbulence accidents decreased through the early 1990s. However, from 1995 through 2000, the turbulence accident rate increased sharply, as annual averages jumped to 13 accidents and 18 serious injuries, including 1 fatal injury in 1997.

High load factors may be the primary source of the sustained increase in the rate of turbulence accidents. Average load factors remained stable at about 60 percent from the 1960s through the early 1990s. However, since the mid-1990s, load factors have increased steadily and now approach 80 percent for the industry. Higher load factors increase the likelihood that one or more people will be out of their seats or seated but not secured during turbulence encounters, thereby increasing the chance of injury. Load factors are likely to remain high.

EXHIBIT 1: TURBULENCE ACCIDENTS AND SERIOUS INJURIES U.S. AIR CARRIERS, 1981-2000

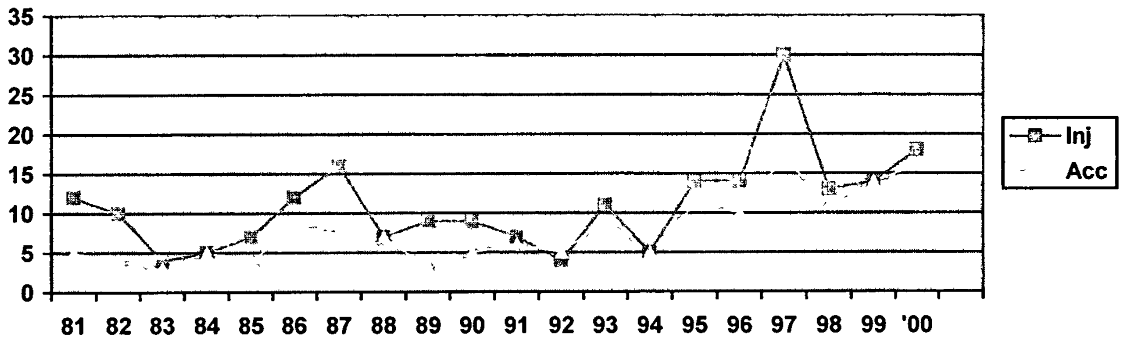
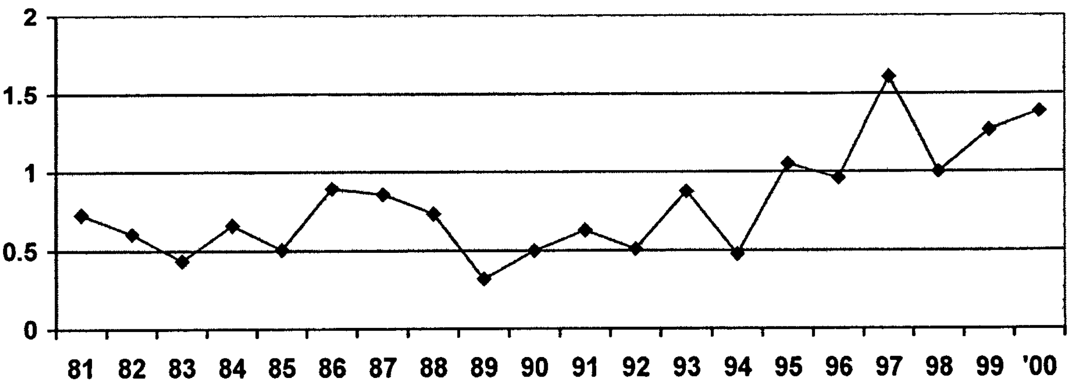


EXHIBIT 2: TURBULENCE ACCIDENTS PER MILLION DEPARTURES



U.S. AIR CARRIERS, 1981-2000

In addition, regional jets are rapidly replacing turboprops. This could be significant for turbulence, as turboprops accounted for just 12 of 156 turbulence accidents (7.7 percent) in the 20-year study period and 13 of 221 serious or fatal injuries (5.9 percent). Those 13 injuries on turboprops included just 2 passengers.

The low shares for turboprops depend largely on two factors. First, many turboprops are too small to permit occupants to move about. The smallest turboprops often have no toilet and may not require a flight attendant. The net result is much less on-board movement. Conversely, the rapid shift to regional jets will increase on-board movement by occupants. Secondly, regional jets will operate routinely at altitudes above 20,000 feet, where 80 percent of jet turbulence accidents occur but where turboprops typically do not operate.

In short, with the introduction of regional jets and the likelihood that load factors will remain above the once stable level of 60 percent, the turbulence accident rate is likely to continue at or above the high levels experienced since 1995. Informed intervention will be required to reduce turbulence accidents, but informed intervention requires an understanding of the basic characteristics of turbulence accidents.

For starters, turbulence is seldom a threat to aircraft. Of the 156 turbulence accidents from 1981 through 2000, just 3 caused substantial damage to aircraft, 1 of which was the lone cargo flight in the data (also the only turbulence accident with no injuries). Therefore, with just 3 exceptions in 20 years, turbulence events qualified as accidents only because someone on board was seriously injured.

Instead, the most common characteristic of turbulence accidents is an injury to a person who is not seated or not properly belted, often despite warnings. The pervasiveness of this factor cannot be overstated. Similarly, injuries are limited in most cases to just 1 or 2 persons. More than 1 person was seriously injured in just 16 percent of turbulence accidents. More than 3 serious injuries occurred in just 6 of the 156 cases (3.8 percent). On average, even when someone was injured seriously enough for the encounter to qualify as an accident, 99 percent of the people on board incurred no injury. Unlike controlled flight into terrain, loss-of-control, or landing short, turbulence is not a threat to most people on board.

Tellingly, no pilots received even minor injuries over the 20-year study period (see Exhibit 3). In fact, no pilots have been injured in turbulence accidents since at least

1974 (the last year of data searched for this paper). The absence of pilot injuries is easily explained, as pilots typically are seated and secured with 4-point belts. That is the point: *turbulence accidents would virtually disappear if occupants were seated and properly secured!*

EXHIBIT 3: TURBULENCE ACCIDENTS AND INJURIES

U.S. AIR CARRIERS, 1981 - 2000

	# Acc	Pax Fatal	Pax Ser Inj.	Pax Min Inj.	Pax On Bd	FA Ser Inj	FA Min Inj.	FA Onbd	Plts OnBd	TOT Fatal	TOT Ser Inj.	TOT Min Inj.	Total On Bd
1981	5	0	7	4	441	5	0	18	11	0	12	4	470
1982	4	0	5	2	327	5	1	18	10	0	10	3	355
1983	3	0	2	6	255	2	1	11	8	0	4	7	274
1984	5	0	2	5	498	3	5	29	13	0	5	10	540
1985	4	0	3	19	228	4	2	18	9	0	7	21	255
1986	8	0	6	29	986	6	18	47	18	0	12	47	1051
1987	8	1	10	68	882	5	9	39	20	1	15	77	941
1988	7	0	2	8	957	5	11	46	15	0	7	19	1018
1989	3	0	8	21	368	1	2	21	8	0	9	23	397
1990	5	1	4	61	532	4	8	24	11	1	8	69	567
1991	6	0	4	21	648	3	4	32	12	0	7	25	692
1992	5	0	1	0	520	3	1	23	12	0	4	1	555
1993	9	0	3	18	932	8	8	48	18	0	11	26	998
1994	5	0	0	0	860	5	3	33	11	0	5	3	904
1995	11	0	7	10	1371	7	1	68	23	0	14	11	1462
1996	10	0	6	28	1169	8	8	40	20	0	14	36	1229
1997	17	1	15	28	2460	14	18	114	38	1	29	46	2612
1998	11	0	5	22	1504	8	8	67	24	0	13	30	1595
1999	14	0	5	87	1582	9	20	71	29	0	14	107	1682
2000	16	0	5	35	1751	13	15	82	36	0	18	50	1869
TOT	156	3	100	472	18271	118	143	849	346	3	218	615	19466

The issue of being seated and secured applies especially to flight attendants. Injuries to flight attendants are remarkably high in proportion to their population on any given flight. Over the 20-year study period, the 156 turbulence accidents caused a total of 3 fatal injuries to passengers (1 each in 1987, 1990 and 1997). In addition, 100 passengers and 118 flight attendants were seriously injured, while 472 passengers and 143 flight attendants incurred minor injuries.

Exhibit 3 shows that passengers accounted for 93.9 percent of persons onboard the 156 accident aircraft, but they accounted for only 47.5 percent of the fatal and serious injuries, and 76.7 percent of minor injuries. In contrast, flight attendants accounted for just 4.4 percent of people onboard but 52.5 percent of serious or fatal injuries and 23.3 percent of minor injuries. These ratios imply that each flight attendant was 25 times more likely to be seriously injured in turbulence than any single passenger. This high relative risk to flight attendants has increased in the past decade. From 1981 through 1990, flight atendants were "only" 17 times more likely to be seriously injured in turbulence; from 1991 through 2000, flight atendants' rate of injury jumped to 33 times that of passengers.

Flight attendants inherently are exposed to added risk in turbulence because their duties require them to be up and moving much of the time. Injuries to flight attendants had several common explanations. Inadequate or no warnings from pilots were the most common factors in injuries to flight attendants. Adequate warnings, in turn, are related to several factors.

Clear air turbulence (CAT). CAT is the factor most commonly cited to explain inadequate or no warnings to the cabin. By definition, CAT is not visible and is not detectable by contemporary technology. Consequently, adequate warnings are precluded. However, CAT is significantly over-reported. About two-thirds of all references to CAT involve cases in which pilots were or should have been aware of increased risk. The most common cases in which allusions to CAT are inappropriate are those in which pilots knowingly fly too close to active storms or visible convection. Two of the more severe turbulence accidents of the past decade illustrate the point.

In October 1990, on a flight across the Caribbean and along the Florida coast, 26 passengers ignored repeated warnings and remained standing. When severe turbulence was encountered, an elderly passenger was fatally injured, 2 passengers were seriously injured and 23 received minor injuries. None of the 65 properly secured passengers was injured. The flight crew later said they had encountered "clear air turbulence in a storm over hang," as they were operating in an area of active thunderstorms. Notwithstanding passengers' irresponsibility in this case, CAT and "a storm over hang" are not consistent.

In May 1998, a 737 flew between two level-5 thunderstorms that were just 14 miles apart or, at best, just 7 miles off each wing. The aircraft encountered severe and sustained turbulence, in which all three windshields shattered and the radome separated in flight. After being coached to the airport by ATC, the captain reported that he had encountered CAT.

These two cases are dramatic, but their fundamentals are quite common. Similarly, many cases involve accidents in which flight crews had received accurate and current forecasts of turbulence, SIGMETS, or information from other airborne pilots about pending turbulence but continued to fly toward or into the turbulence, and often with inadequate warning to the cabin.

At its heart, CAT implies something akin to "how was I to know?" Most cases in which CAT is cited fail this test of utter surprise. The point here is not to challenge every report of CAT or to imply that CAT is not a real problem. Instead, the point is simply that CAT often is cited inappropriately and, as a result, CAT is substantially over-reported.

Yet, notwithstanding substantial over reporting, "real CAT" still explains up to 20 percent of the 156 turbulence accidents. CAT will not be reduced without better detection, better communication of detection, and better forecasting. Improvements in those areas would benefit CAT, but other turbulence events also could benefit if turbulent conditions were identified with more precision. This is more easily said than done -- at least for an affordable price.

Simply put, turbulence forecasts must become more precise if they are to help reduce turbulence accidents and injuries. Forecasts often include such enormous amounts of airspace that the forecasts have limited utility.

In contrast to the complexity of weather forecasting and CAT detection, some turbulence accidents and injuries are explained by a simple lack of knowledge among aviation professionals about the risk of injury. Flight attendants, for example, often illustrate a lack of knowledge about their own risk during turbulence. Some flight attendants get hurt while tending to one more discretionary duty before seating themselves, or get hurt after leaving their seats to tend to a passenger who has left his or her seat, or to close an overhead bin that has opened, etc.

Other cases involve a mixture of these and other factors, including: (1) corporate policies that, in practice, place higher priority on continued cabin service at the expense of flight attendants' safety; (2) pilot decisions that needlessly expose flight attendants to added risk; and (3) tedious on-board communications procedures that either take too long or simply break down before everyone gets the word.

In the end, despite the requirements of their jobs and the more varied explanations for injuries to flight attendants, their bottom line is similar to that for passengers: injuries virtually disappear when everyone is properly secured. Proper briefings and on-board warnings, along with adequate information available to the flight crew, can best ensure that occupants are properly seated and secured.

Whether occupants are properly secured or not, another obvious strategy is simply to avoid turbulence whenever possible. Though avoidance is not always possible, as when turbulent conditions cover an entire region of the country, the evidence is convincing that turbulence accidents are far less common among carriers that place priority on turbulence avoidance.

Exhibit 4 shows the number of turbulence accidents for the past 10 years (1991-2000) for selected air carriers in the U.S. United is at the top of the list with 26 accidents, 41 serious injuries, and 1 fatality. American ranks a distant second with 16 accidents and 19 serious injuries, while Delta ranks a more distant third with 11 accidents and 11 serious injuries.

Since United and American are the two largest carriers, their ranking is not a surprise. However, at the other end of the spectrum is Northwest with just two turbulence accidents and three serious injuries since 1981 (in fact, just 2 accidents since at least 1974).

Disparities like 26 or 16 versus 2 cannot be explained only by the size of the respective carriers. Though each of the big 3 carriers operates about twice as many flights as Northwest, they do not operate 13 or 8 times as many flights. Similarly, route structure, though a factor in turbulence, does not explain such disparities. Northwest has operated nationally for some time, including a hub at Memphis, and its exposure in the Western Pacific is as high as any other U.S. carrier, as implied by its former name, Northwest Orient. In short, Northwest's volume and route structure expose Northwest to turbulence on a scale similar to other large U.S. carriers.

EXHIBIT 4: TURBULENCE & WAKE TURBULENCE ACCIDENTS AND INJURIES,
BY SELECTED U.S. CARRIERS, 1991 THROUGH 2000

	Accidents	Fatalities	Serious Injuries	Minor Injuries	Total OnBd
Air Wisconsin	2	0	3	1	61
Airtran/Valujet	2	0	2	1	176
Alaska	3	0	4	6	258
America West	6	0	6	11	716
American	16	0	19	86	2669
American Eagle	3	0	3	0	104
Atlantic SE	3	0	3	0	118
Continental	6	0	6	79	525
Delta	11	0	11	24	1647
Northwest	2	0	3	3	333
Southwest	4	0	4	1	431
TWA	2	0	2	4	279
United	26	1	41	56	4511
US Airways	5	0	7	18	543
All Other	13	0	15	45	1227
TOTAL	104	1	129	335	13598

The difference appears to be a strategic decision by Northwest to avoid turbulence. As described by James McKenna in Aviation Week and Space Technology (July 27, 1998), "Northwest leads the industry in turbulence monitoring and avoidance," spending $2 million annually "to maintain its large, two-station meteorology department, widely recognized in [the] industry as a pacesetting operation. Its meteorology office ... prepares a turbulence plot for each of its flights and updates crews with information ... directly to the cockpit." (p. 68) In addition, Northwest incorporates historical data that identifies areas prone to turbulence, including mountain rotors.

Northwest's expansion in the late 1980s and early 1990s may provide the most convincing evidence that the program can make a major difference. In that period, Northwest acquired several carriers, most notably Republic, which previously had experienced relatively high rates of turbulence accidents. Yet, the acquired crews and city pairs had no more turbulence accidents after being absorbed into Northwest.

Several other carriers in recent years have chosen to purchase weather services from Northwest. Those carriers include Alaska, Continental and Delta, and all three have reduced the frequency of turbulence accidents in the past several years.

The point here is not to single out a particular carrier or product for praise or criticism. Rather, the point is that corporate policies and priorities *can* influence the frequency of turbulence accidents and injuries.

SUMMARY OF PART ONE.

Part one has shown that turbulence accidents and injuries have increased sharply, both in absolute numbers and when measured by rates, and that the higher numbers are expected to continue and probably increase. The relative risk is especially high for flight attendants, but passenger injuries also remain common. Common characteristics of turbulence accidents include:

1. occupants who are not seated and properly secured (accidents and injuries would nearly disappear if this problem could be resolved);

2. continued flight near active weather cells or known convection and turbulence;

3. inadequate warnings to the cabin of impending turbulence;

4. a less than full understanding of turbulence and its risks, both among some pilots and cabin crews;

5. the inability to detect CAT;

6. forecasts often identify such large portions of airspace that the forecast has little practical use; and

7. weaknesses in corporate policies.

PART TWO: OPTIONS FOR REDUCING TURBULENCE ACCIDENTS AND INJURIES

Thunderstorms, convection, the collision of cold and warm air, etc., are not about to disappear. The challenge is to avoid turbulence, or to minimize the on-board risk when turbulence is encountered. Part Two of this paper reviews strategies for reducing turbulence accidents and injuries, with some assessment of feasibility, benefits, and costs. Options are organized around three broad strategies: turbulence avoidance; ensuring that occupants are seated and secured; and turbulence detection.

STRATEGY ONE: TURBULENCE AVOIDANCE.

Carriers could reduce turbulence encounters by establishing turbulence avoidance as a core operational strategy. This option would build on the Northwest model but, to be fully applied, it requires three actions by air carriers. First, clearly establish and sustain a policy of avoidance. Second, review procedures for acquiring and disseminating PIREPs, SIGMETs, and other weather information, including pre-flight briefings. Third, consider establishing adequately staffed meteorological (met) departments, with constantly updated information transmitted to crews. Though small carriers may be hard pressed to establish a met department of the necessary scale, they could purchase outputs from other met organizations, as Continental and Alaska do, or they and larger carriers could establish a met organization for a consortium of air carriers.

The primary costs associated with this option are: (1) the extra time and fuel consumed while going around convection and other sources of turbulence; and (2) the cost of establishing and sustaining a met department, or of buying met products. Northwest, for example, now spends about $3 million annually on its met department. The option, therefore, is not without some cost and some administrative challenge.

However, the strength of turbulence avoidance as a core strategy is the evidence that it *can* reduce turbulence accidents. It can reduce CAT events that repeatedly occur in isolated areas, plus those events near active cells, near known convection, or near existing turbulence. The Northwest experience *conservatively* indicates that this strategy alone could reduce turbulence accidents and injuries by half or more.

Turbulence avoidance is feasible with existing systems and information. Costs are reasonable and benefits are real. The bottom line is that turbulence avoidance is cost-effective.

STRATEGY TWO: ENSURE OCCUPANTS ARE SEATED AND PROPERLY SECURED.

As stated in Part One, turbulence accidents and injuries (including those incurred in reported incidents) would virtually disappear if passengers and flight attendants were seated and properly secured during turbulence. This strategy is easily stated, but not so easily achieved. Below are several component options that could produce real progress toward this goal. The principal strength of these options is that they are feasible right now and at almost no cost. Some carriers will conclude that they already are pursuing one or more of these options, but other carriers may not conclude that, or may find they are pursuing only portions of the strategy.

2A. On-Board Communication Procedures. Carriers should review on-board communication procedures to ensure that warnings from the cockpit to the cabin are standardized, clear, and timely. Warnings from the cockpit should be clearly stated to avoid any ambiguity that may discourage occupants from remaining seated and secured. Trends since 1995 suggest that carriers especially need to ensure standardization and clarity in communications between the cockpit and flight attendants. This can be done with standardized codes, as several carriers already do, or simply and clearly stated directions to be seated promptly. The point here is to ensure that the cabin crew understands when *not* to consider one more discretionary duty before getting secured, or when *not* to worry about securing carts and the like, while passengers must understand when *not* to reach for something in the overhead or when *not* to walk to the toilet.

Communications procedures also need to address all-clear instructions. Many carriers have relatively clear instructions, at least much of the time, on the front end of turbulence, but fail to state clearly when on-board movement can be resumed safely. As a result, passengers and (especially) flight attendants may respond to the initial warning but, later, may decide independently that the threat has passed and movement can be resumed, thereby exposing themselves to the risk of injury. All-clear statements to flight attendants can be addressed with a review of internal procedures, but an effective all-clear statement for passengers requires that the initial warning include a statement that passengers will be advised when they can resume safe movement.

Finally, carriers should review procedures for transmitting warnings and information to flight attendants. Carriers need a simple and quick process rather than a cumbersome and involved procedure, as with an intercom call to one flight attendant, who then passes the word onto another flight attendant, and so on. Such a procedure simply takes too long and can easily break down, resulting in some flight attendants either being advised too late or not at all. Clear communication *will* reduce ambiguity for cabin occupants and thereby will reduce injuries, and it will do so at *no cost.*

2B. Crew Training. Pilots and flight attendants should be educated and trained on the nature of turbulence, aircraft behavior during turbulence, and subsequent risks to personal safety. This does not mean that flight attendants must become meteorologists. Rather, flight attendants would be educated on how turbulence can affect sure footing or, worse, how associated "G" loads can force them off their feet. The education would emphasize the standard communications recommended above, prioritization of tasks when turbulence warnings are communicated, the nature of turbulence, how it can affect the rear of some aircraft more than the forward sections, and that flight attendants must protect their own safety in order to ensure that they can function after the turbulence, in case passengers or other cabin crew need assistance. Such education might require no more than a one-time commitment of two hours per crewmember, and/or a brief section during initial training for new hires.

Pilots' training and education would be a bit more extensive but, again, the objective would not be to turn pilots into meteorologists. Instead, training would emphasize recognition of conditions that are conducive to turbulence, recognition of convection, an understanding of the greater risks in the rear of certain aircraft (those with engines hung from the wing), standardized communication of turbulence warnings to the cabin, including all-clear signals, and the policy of avoiding turbulence whenever possible.

The training would be inexpensive, particularly when compared to options that would emphasize new technology. The core information has been established for years. The only cost would be the addition of one or two hours to initial training and adding brief written or oral material to recurrent training. The bottom line is that, in conjunction with a corporate policy to avoid turbulence, plus improved on-board communications procedures, crew education could be the third peg necessary to virtually eliminate turbulence accidents.

2C. Interior Cabin Design. The final step in the low-cost options for reducing turbulence accidents and injuries would focus on mitigating the opportunity for injury when significant turbulence is encountered. Options include adding hand-holds to cabin interiors, as Continental has done on some of its Airbus fleet, increasing the padding on arm rests, and adding hand-holds to galleys, where about 40 percent of flight attendant injuries occur. This approach would be very low-cost if it focuses on newly purchased aircraft. Retrofitting would be more costly and likely would be limited to C-checks and D-checks (heavy maintenance), or perhaps only to D-checks. Either way, the downside is that fleet penetration will be slow.

STRATEGY 3: TECHNOLOGICAL OPTIONS TO DETECT TURBULENCE.

3A. CAT Detection Systems. By definition, CAT is not visible and is not detectable by contemporary technology; it requires new detection devices and systems if it is to be avoided. To be acceptable to air carriers, a turbulence-avoidance system must provide enough warning to get everyone seated and secured. New systems also must pass demanding practical tests.

The air carrier industry indicates that a minimum warning of two to three minutes is required, with false warnings limited to a maximum of 5 percent. Note that this approach wisely assumes that CAT detection is meant to address getting folks seated when turbulence is imminent; it does not seek on-board warnings to facilitate last-second pilot inputs to divert. That qualification suggests a second test: do no harm. Third, systems must be easily integrated into cockpits without adding to pilot workload.

CAT detection solutions typically focus on on-board weather radar, either as stand-alone systems or in coordination with information from ground-based systems. Efforts to develop new detection systems include new technology and improvements in existing X-band radar technology.

Light Detection and Ranging (LIDAR), which is based on laser technology, has received most of the recent attention in the realm of new technology. However, LIDAR faces major practical limitations. LIDAR requires more substantial and heavier cooling systems than the air-cooled systems used by X-band radar. To double its accuracy, LIDAR requires about a 4-fold increase in weight. Current LIDAR is accurate within a maximum of 5 miles at altitude. To meet the industry's informal requirement of a 2- to 3-minute warning, LIDAR must be accurate up to 20 or 25 miles. To achieve this with current LIDAR technology, the equipment could add 200 pounds or more to the aircraft. It also would require antennae and platforms that will not fit in radomes. Finally, the requirement to limit false warnings to about 5 percent simply will not be achievable with LIDAR for a decade or more.

Even if LIDAR were to eliminate all accidents associated with CAT, it might save the industry 5 to 8 serious injuries per year (which includes some injuries saved by pin-pointing known turbulence). Unless LIDAR achieves a sudden and quantum breakthrough, the substantial technical challenges and developmental costs still ahead suggest that LIDAR will never satisfy cost-benefit or "business case" requirements.

The alternative to LIDAR is to focus on improvements to existing on-board weather radar systems. Today's X-band radar X-band radar returns signals from water droplets. X-band adequately depicts most large weather systems or active weather cells and significant convection, all of which should inform crews of increased risk of turbulence.

However, X-band has its limits. Since X-band reflects moisture, it can identify the *wet* tops of cells, but X-band does *not* reflect dry tops well (snow or hail). Similarly, a strong cell can absorb most or all of a radar beam and thereby hide (or "attenuate") smaller but significant cells behind the strong cell. In addition, because a beam's diameter increases with distance, two cells or returns may be displayed as a single return if the diameter of a beam becomes large enough to contact both cells. The widening beam also causes resolution to deteriorate exponentially with distance; as distance doubles, resolution deteriorates by a factor of four.

Due to such limitations, current on-board weather radar technology can miss low-density convection or cells, and can not identify clear air turbulence, since CAT lacks water particles. In addition, the resolution and precision of current systems fall far short of the precision demanded of a turbulence-avoidance system. These limitations have been understood for a generation or two; if precision necessary for CAT detection were easily and cheaply available, it would have been in place for some time.

Yet, in contrast to LIDAR, enhanced X-band has a chance to meet cost-benefit tests, *provided* that efforts focus on incremental change to software and existing cockpit displays. Since air transport aircraft are required to have weather radar, incremental improvements may be achievable for low marginal costs, with the improved information displayed on existing weather displays.

The downside to this approach is that it indeed will be incremental, and improvements will be added only to newly produced aircraft, as the cost of retrofitting could be prohibitive when compared to competing demands for safety resources. In the end, enhanced X-band will not change the experience with turbulence very quickly.

3B. New Graphical Displays. Another commonly suggested technical solution is to create a real-time graphical display that incorporates on-board data with several sources of ground-based, alphanumeric information, as in ACARS. The strength of this option is that it would present a single graphic to transmit information at a glance to the crew. The downside is that up-linked data is not now part of the main instrument panel. Consequently, in addition to developmental work, this would require a full certification process, complete with a demanding test to ensure against the possibility of "hazardous misleading information" on the primary display (a 1-in-100,000 standard). At best, incorporation into primary on-board displays would be at least 10 to 12 years away.

An alternative approach could use a secondary display, such as a non-critical display in the cockpit or displaying graphical information on a laptop. This likely could be achieved within just two or three years. However, in addition to developmental issues, the secondary display would face practical limitations about adding a non-critical display on the instrument panel, where space already is at a premium. The use of laptops faces a similar limitation on the available space in many aircraft. In the end, as with finite funds, the ability of turbulence to compete for limited real estate is doubtful.

3C. Improved Forecasting. Improving the accuracy and precision of weather forecasts appears to be the most promising of the technology options. Forecasts often identify such large pieces of airspace that their utility for avoiding turbulence suffers. However, spending finite engineering capacity on forecasting technology *only* to address turbulence has limited promise. Yet, improvements will happen, but independently of turbulence. The promise lies in secondary benefits to turbulence from more broadly based efforts.

CONCLUSIONS

Turbulence accidents and injuries have reached historically high levels and are likely to continue increasing. If the industry is to reduce those accidents and associated injuries and costs, conscious intervention will be required. However, competition for funding and other resources is the primary limiting factor, as the costs and risks associated with turbulence pale when compared to less common but more severe accident scenarios. Consequently, interventions must be inexpensive and organizationally feasible.

This essentially rules out complex and costly technological fixes, such as LIDAR. The role of technology in resolving turbulence accidents and injuries will be limited to the evolution of improvements that address other issues, with some secondary benefit for turbulence. Instead, efforts to reduce turbulence accidents should focus on two key strategies:

Turbulence avoidance; and
Ensuring occupants are seated and secured.

Below are some options that can advance those strategies, and do so at very little cost, and without severely taxing organizational capacity. The options are listed roughly according to their ability to combine effectiveness, feasibility and low cost.

1. Make turbulence avoidance a core operating strategy, complete with a review of internal procedures for obtaining and disseminating weather information.

2. Review on-board communications procedures for their clarity and simplicity, including standardized all-clear statements and straight forward advice to passengers when appropriate.

3. Educate and train pilots on the nature of turbulence, its indicators, and associated risks in the cabin; include training on avoidance policy and clear, standardized on-board communication procedures.

4. Educate flight attendants on the nature of turbulence, the risks they face from turbulence, and the need to prioritize their activities when advised of impending turbulence.

5. Make low-cost but useful changes to interior designs, either during heavy maintenance or when purchasing new aircraft, such as adding recessed handles in the galley, handles on overhead bins, padded arm rests, etc.

附錄五

航空燃油污染調查

Fuel's Fuel

whether it's from Afghanistan or Australia

By

Mike Watson

Australian Transportation Safety Bureau

Fuel's Fuel, whether it's from Afghanistan or Australia

Mike Watson, ASI, Australian Transportation Safety Bureau

Aviation fuel, is a necessary component of the operating systems for powered aircraft; it is replaced more often than any other component, and its quality is no less critical to flight safety than any other component of an aircraft's power system.

Shortly before Christmas 1999 a number of Avgas powered aircraft in Australia experienced unexpected power losses. The power losses were investigated, and a mildly adhesive black substance we referred to as 'gunk' was found on brass surfaces in the fuel systems of these aircraft. The black 'gunk' was found to be a product of reaction between the brass and a contaminant in the fuel known as ethylene diamine. No one was hurt as a result of contaminated aviation fuel, and there were no accidents that could be attributed to a loss of power caused by fuel contamination. At the time of the crisis the fuel refiner responded immediately and recalled all Avgas that had been manufactured at the refinery, and the Australian Civil Aviation Safety Authority grounded all Avgas powered aircraft that could have been contaminated until it was known that they were safe to fly.

The contamination event caught everyone by surprise. Such an event had not been seriously considered as a potential hazard to aviation anywhere in the world, and therefore the consequences had not been considered. The reasons behind why the fuel became contaminated were unexpected.

Australian legislation requires that the Australian Transport Safety Bureau investigate transport accidents, serious incidents, incidents and safety deficiencies. A safety deficiency is any situation that can reasonably be regarded as having the potential to affect adversely the safety of aviation. Although an investigation of fuel quality was not within its traditional scope of work, the safety potential of fuel that was not fit for purpose was clearly identified as a significant safety deficiency. An Australian Transport Safety Bureau safety investigation therefore followed the grounding in January 2000 of thousands of piston engine aircraft across eastern Australia as a consequence of the fuel contamination event.

At the time of the event, there was a concerted effort to define what the contaminant was (its concentration in the Avgas was low); how the contaminant had got there; and what the contaminant's behaviour would be in an aircraft fuel system.

In the initial response a method to guarantee that aircraft would be safe for flight was developed, and a testing process to detect ethylene diamine was also developed in a number of weeks. Components for the required test kits were sourced from all over the world.

The Australian Transport Safety Bureau's investigation not only looked at what had happened, it also looked at what defences could have prevented the fuel contamination from happening and why they didn't. The investigation also looked at lessons that could be learnt and applied to other aviation systems. That included what could have happened if a similar contamination event occurred in a large turbine-engine passenger aircraft operating with contaminated jet fuel.

The main defence against any safety-critical system failure in an airliner is to have backup, or redundant, systems for any system that is essential for safe flight. The problem with fuel storage and supply systems in an aircraft is that they simply don't have a redundant backup. If fuel is contaminated, the contaminant would be likely to be supplied to all an aircraft's engines at the same time, and could make them all unreliable at the same time.

The Australian Transport Safety Bureau investigation found that a temporary variation in the production process at the refinery that produced the fuel in the contamination event in late 1999, involved problems with reduced caustic wash and increased acid carry over. That led to an increased dosage of an alkaline anti-corrosion chemical in the process stream by a contractor. That was not totally removed from the final Avgas. The normal tests for the quality of Avgas did not, (and would not be expected to) pick up the very small concentration of the chemical contaminant in the Avgas. That small concentration was sufficient to react with brass in aircraft fuel systems and form the black 'gunk' that clogged them.

A number of organisational defences existed to enhance the likelihood of receiving fuel that is fit for purpose. Australian civil aviation is controlled by a system of regulatory oversight that is required to regard the safety of air navigation as the most important consideration. Fuel quality has the potential to be safety critical, therefore there is a potential for some form of regulatory oversight to reduce the probability of fuel that is not fit for purpose being put into an aircraft. Other regulators (such as occupational health and safety regulators, or trade practices regulators) also have the capacity to consider fuel quality as a part of their mandate. If there is no clear delineation of responsibility between these regulators, then a significant diffusion of responsibility can exist, which would reduce the effectiveness of the defence of regulatory oversight.

Aviation fuel is produced to meet one or more of the international standards that are used to define the specific fuel. An expectation exists that delivered fuel that met the standard would be fit for purpose, and yet the contaminated fuel met its relevant standard at all times. The contaminant that existed in this case had not been considered in the development of the standard, nor was the standard expected to pick up all possible forms of contamination, or all possible other properties that might make fuel unfit for its purpose. A standard will only define the nature of a product at one instant in that product's life, and cannot guarantee that the product meets the standard at other times in the product's life, unless specified storage and handling requirements are met after the specification test. A standard cannot be used as a 'silver bullet' to ensure that aviation fuel is fit for purpose; it can only be seen as one of a number of defences that increase the probability that delivered fuel is fit for purpose. A standard that defines a product's performance will provide explicit parameters. Users may infer other parameters from the explicit parameters, however if those inferred parameters are safety critical, then that inference may not be safe. There is a reasonable reluctance to incorporate more physical parameters into a fuel standard, as that would mean that fuel manufacturers would have to undertake more testing on the fuel, and therefore the implicit safety-critical parameters could not always be articulated.

Conclusion

As the primary defence of a redundant system is not available to protect against the safety critical problem of fuel quality, we could reasonably expect there to have been a number of fuel quality related accidents in the recent past; however that was not so. That can only be attributed to a highly reliable system for manufacture and distribution of aviation fuels, with a well-managed quality control process.

Despite this, it is clear that a lack of in-depth defences on the part of any group that has a responsibility towards maintaining fuel quality, be they refiner, distributor, regulator or consumer, could lead to an unexpected reduction in reliability of aircraft power systems.

This Avgas contamination event must be seen as a clarion call to highlight an aspect of the system of safe aviation that is more vulnerable to a lack of in-depth defences than most other safety critical aviation systems.

附錄六

航空公司面臨之挑戰、選擇、結果

The Airline Industry

Challenges – Choices – Consequences

By

James L. Cole, Jr.

Air Transport Association of America

The Airline Industry

Challenges - Choices - Consequences

James L. Cole, Jr. (MO4544) - Air Transport

Association of America

During a thirty-year career in the U.S Air Force, "Jack" Cole logged 2,000 hours in DC-3's and also has extensive heavy jet instructor and check pilot time. As Commander of the 89th Airlift Wing, he directed and operated VIP air transportation for the U S President and senior government officials. He also directed the entire safety program for the U.S. Air Force, managing all flight, weapons, explosives, and ground safety. Cole is currently the Senior Director, Safety, for the Air Transport Association of America.

Today we stand on the threshold of the centennial celebration of powered flight. The success of the Wright Brothers' brave and daring endeavor at Kitty Hawk, North Carolina, on December 17, 1903, opened a new dimension for business transportation and travel. Who would have thought that by the year 2000, the U.S. airline industry would: [1]

Enplane more than 1.8 million passengers every day, 85 percent of whom have a choice of two or more airlines.

Operate in excess of 24,000 domestic and international flights per day, directly employing nearly 680,000 people in strong, well-paying jobs, and pumping nearly $300 billion into our national economy each year.

Carry more than 23 billion ton miles of cargo (freight, express, and mail) every year.

Operate aircraft that cost on average over $50 million.

Provide the most energy-efficient mode of mass transportation for trips exceeding 500 miles.

This is a success story of amazing proportions, but that very success has created a set of formidable challenges that demand resolution, and tough questions that require answers. Let me list a few.

How do we work with the government to design and manage an air traffic

control (ATC) system that truly meets the needs of the public?
How do we continuously improve upon the safety performance of what is already the safest mode of transportation?
How do we provide a better, more efficient, and pleasant flight experience at the lowest possible cost?
How do we move packages and cargo even more efficiently from door-to-door--around the world?
How do we best balance our interests in the environment with society's need for safe and efficient air transportation?

The air traffic control system and total system capacity demand the immediate attention of everyone in the aviation business. Because ATC is involved in the movement of all commercial airline traffic, the capabilities and efficiencies of ATC have a direct bearing on the schedule and performance of airlines. We have the greatest compliments and praise for the air traffic controllers - what they do and how they do it. But the government's air traffic control system is increasingly unable to handle growing demand.

Even in perfect weather, on a perfect day, with no equipment glitches or personnel shortages in ATC facilities, the air traffic control system is periodically overloaded. During inclement weather and on less-than-perfect days, the congestion and delay problems become much worse.

More importantly, we know that the world is not perfect and the skies are not always clear and pretty. There are equipment failures, and there are personnel shortages, and there most certainly are periods of bad weather. These cause backups and stackups that geometrically expand and reverberate through the system. Despite many claims to the contrary, weather is the primary cause of delays. Approximately two-thirds of the time, delays can be attributed to weather. I have yet to see the technology that will tame Mother Nature, although improved equipment in the air and on the ground can provide advanced warnings and effective work-arounds, to avoid trouble and minimize delays. That technology, coupled with the eventual realization of a "Free Flight" satellite-based air traffic control system, to include Controller-Pilot-Data-Link Communication and Automatic Dependent Surveillance-Broadcast equipment, should decrease the number of weather delays significantly, but weather will remain as the primary cause of delays.

The airlines are sometimes portrayed as uncaring and unsympathetic to their customers, who experience the personal inconvenience and even downright trauma of travel delays. Be assured that the airlines are working hard to provide better information and better responsiveness by airline employees to address passenger concerns. They are also actively engaged in working the system capacity and technology issues - and all for good reasons. Fuller airplanes - required for the lowest fares - mean that there are fewer empty seats to accommodate delayed passengers. In recent years, there have been an average of nearly 1,000 daily flight delays of 15 minutes or more. The cost of these delays to the airlines and their customers is estimated at $6 billion per year.

These costs include:

- Extra fuel burned awaiting takeoff
  - Extra crew cost from delays
- Extra airframes bought or leased for back-up
- Extra nights on the road for passengers

So what do we do in the near-term and the long-term to work the air traffic control system and total system capacity issues?

Q. Prohibit airlines from over-scheduling during peak arrival/departure preference periods?

A. First, it is important to note that so-called over-scheduling by carriers only accounts for approximately 10 percent of the total delays. Second, of course, what is characterized as "over scheduling" is really just meeting the public's demand for air transportation. The only over-scheduled flight is an empty flight.

Q. Accelerate new technology research, development, test and acquisition?

A. Certainly, but current assessments for system capacity increases, based on known new technology in the foreseeable future, do not exceed an estimated 15 percent. That will clearly not be sufficient, but acceleration of the pace of deployment is a key factor in achieving the required capacity.

Q. So what, then, could be the high-leverage endeavor to expedite air traffic control,
reduce delays and increase total system capacity?

A. The answer is: concrete and lots of it. Airport capacity improvements are desperately needed to reduce delays, increase system capacity and improve the efficiency of the national air transportation system. When we realize that air traffic volume increased by 40 percent over the past twenty years, and airport runway capacity increased at a much lower rate, during the same period of time, we have suddenly framed the problem and identified a high-leverage solution. For example, Atlanta Hartsfield has a planned additional 9,000 foot runway that is in the final Environmental Impact Statement (EIS) review stages. If the current EIS review process proceeds as planned, the runway can be built and put in service by May 2005. The cost will be $1 billion and will increase the airport's capacity by 50 percent - from 180 operations to 270 operations per hour. [2] Similar improvements at a dozen other target airports in the United States will produce similar increases. So why have these improvements not been undertaken and completed before? Because it takes only two years to build a runway and ten years to fight the battle to get it approved.

As I said - challenges, choices and consequences.

Let me turn to another major issue of significant importance to all of us in the aviation business. That is the issue of costs to run an airline effectively, efficiently and profitably. As most of you are aware, there is no shortage of experts on the subject of how airlines should be operated. Unfortunately, many of these same experts have very little knowledge regarding the operational imperatives and constraints that shape and define airline operations.

Airlines, too, face challenges, choices and consequences. An airline must operate as a business, and this includes some amount of profit. If they do not do this, they will no longer exist. Let me provide a brief summary of the numbers for the year 2000 to illustrate the point. Load factors - the percentage of airline seats filled - were at an all-time high last year.[3] Considered in aggregate, it was a pretty good year for U.S. air carriers. The net income for U.S. scheduled airlines was approximately $2.6 billion.[4] But, it was only half of the 1999 total. Let's take a further look back to see what has happened to U.S. airlines in the past.

The message here is that the well-being and profitability of airlines are dependent on forces and factors beyond their control. The period of post-deregulation struggle and adjustment was very difficult. Desert Shield/Desert Storm produced skyrocketing fuel prices. This is a rough business and a wild ride. So what are the real forces and factors that determine an airline's level of service, profit margin and downright survival? Let's take a look.

The four factors or determinants of an airline's profitability and survival are traffic, capacity, yield and unit cost.[5] Traffic and capacity are driven by market forces and system capability to handle demand. From that, you get a load factor, which is basically the percentage of full seats per aircraft. For the year 2000, the load factor was 72.4 percent , which represented a 1.4 percent increase over the previous year.

The yield and unit cost produce a break-even point. For 2000, this was 67.3 percent, which represented a 2.9 percent increase over the previous year. So, if the air carriers could fill two-thirds of their seats over the year 2000, they would break even at the operating level. With a load factor of 72.4 percent, they did slightly better than that, which yielded an operating profit margin of 5.5 percent and a net profit margin of 2.0 percent, which was 2.5 points less than the previous year. This means that airlines can expect to keep about two cents from every dollar of revenue for profits, while the average for U.S. corporations is about six cents from every dollar.[6]

Now, let's look at the forces that will shape, drive and determine the numbers for 2001 and beyond. Fuel costs are a constant item of intense attention and focus for the airlines, but for most people, energy and fuel do not become high-visibility items until you have the specter of a California crisis and daily sticker shock when you take your automobile to the service station. Airlines are obsessed with fuel prices, and here is why. Fuel costs represent their second largest item of expense, and we all know what is happening with fuel prices.[7]

Let's turn to another market force and driving factor that directly influences an airline's service, profitability and well-being. This, too, is a cost, and it is driven by an even greater range of forces than fuel costs. I am talking about personnel and labor. Airlines, or air operations of any kind for that matter, require top-quality, highly-trained and extremely proficient people to maximize effectiveness and efficiency, guarantee safety and ensure the continued competitiveness and even existence of the airline. Many superb professionals enable the airlines to do the right things the right way. Pilots, mechanics, flight attendants, dispatchers, freight managers, ramp supervisors, as well as staff specialists which include financial planners, meteorologists, computer software experts, and many others. There are certainly market forces at work here.

Let's focus on pilots for the moment. Last year, United Airlines' pilot contract set a new standard for pay and benefits. Delta Air Lines followed suit and raised the bar even higher in 2001. But there is much more than the "me too" factor at work here. As the airlines enjoyed relative periods of prosperity over the past six years, employee unions were encouraged to press for increased pay and benefits. Fueled by air traffic growth, airlines are hiring pilots at an increasing rate. Both pilots and mechanics have become an even more precious and expensive commodity as air traffic continues to increase. The net result is higher labor costs for the airlines. So, a major U.S. carrier is compelled to provide a 25 percent to 35 percent pay increase to its pilot force over a five-year period. This translates into a Boeing 777 pilot who flies 78.75 hours per month, not counting overrides, receiving over $300,000 per year in 2004. The CEO of the carrier has estimated that the pilot raise will cost the airline $500 million for the first year of the four-year contract and more than $2 billion over five years including retroactive pay.[8] In the event that a contract had not been signed, there would probably have been a pilot strike. For the sake of comparative estimates, a one day stand down by Lufthansa's pilots this year cost that airline at least $23 million.[9]

The third major issue for coverage is the airline customer. During the past decade, the increased availability and affordability of air travel for business and pleasure have produced a revolution of rising expectations, particularly in the United States. Everyone expects to go by air where they want, when they want, at a price they want, with no hassles or inconveniences along the way. Passenger expectations, and even demands, have changed dramatically from the days of a rare few-times-in-a-lifetime, white-knuckle experience, where you hoped the number of landings equaled the number of takeoffs.

There is a lot that is good and done right by airlines operating in the current system. Travel by air for business and pleasure is remarkably safe, reasonably priced, and most passengers arrive at their destinations on time and with their bags as well. Nevertheless, a recent article in a Newsweek magazine headline blared "Why Flying is Hell" with words to follow, such as "it's war" and "isn't there a way to fix this mess?" In a Newsweek poll, 57 percent of travelers stated that the experience of flying has become worse over the past five years. The biggest complaints: 29 percent cited delayed flights and 27 percent cited cramped quarters on the aircraft as the worst thing about air travel. However, a majority (59 percent) said they were not willing to pay more for better service.[10]

Approximately one in four flights was delayed or cancelled in 2000. It is also true that over two thirds of those delays were weather-related and compounded by backups and stackups at airports incapable of handling high volumes of traffic in bad weather conditions.[11] As previously stated, the volume of air traffic increased by 40 percent in the last 20 years. In 2000, U.S. air carriers enplaned over 665 million passengers. In the next ten years, that number will exceed one billion annually and the volume of air traffic will again increase by 40 percent.

So, if we can't alter the weather, and improved radar and air traffic control work-arounds notwithstanding, what can we do to handle the current volume of traffic and the projected increased volume of traffic?

Look where the congestion really is and where the delays truly occur. The answer is at airports. More concrete for necessary runways, ramps, and gates will go far to solve our current dilemma and prevent even greater problems in the future. Let us consider some key airport facts. According to the FAA Aviation Capacity Enhancement Plan, the top-ten airports (ranked by enplanements) handle 37 percent of the enplaned passengers and the top-twenty airports handle 59 percent of the enplaned passengers. Ten large hub airports accounted for 64 percent of all delays in 1999, and these same airports handled only 31 percent of the total enplanements. [12]

Between 1991 and 2000, only six new runways became operational at large hub airports. Only five new runways are planned, proposed or currently under construction at the top-twenty airports for 2006 and beyond. In the meantime, air traffic has increased by approximately 40 percent in the last 20 years and is estimated to increase by 40 percent in the next 10 years. The six new runways that have been built in the past 10 years were at six of the 30 busiest airports in the U.S., which handle 70 percent of all air traffic. Currently, the rate of air traffic growth far exceeds the rate of runway and airport capacity growth. Airline flights alone are projected to rise from 26 million in 2000 to 36 million in 2012.[13] John Carr, President of the National Air Traffic Controllers Association, is on record as stating that "fifty miles of concrete poured at our nation's 25 busiest airports will solve most of our aviation delays". [14] The FAA is also on record by stating that: "Expanding the nation's airport infrastructure is the most direct and effective means of ensuring adequate system capacity."[15] There is a clue there, and if we don't seize it and do something with it, the delay problems get worse at an ever increasing rate.

We must focus our efforts and resources on increasing airport capacity growth in terms of additional runways, ramp space and gates. Until we do, we will fall further behind, and both the frequency and severity of delays will increase. This will not be easy, and it will not be inexpensive.

There is no "silver bullet" but it is time to stop finger-pointing and blaming others for our collective problems. "Pouring more concrete" is the one single thing we can do to produce the greatest leverage and results to solve our capacity, congestion and delay problems. All of us had better get focused and get with it. The challenge is there. The choices are ours. And, so are the consequences.

附錄七

奧運會期間之空中交通管理

AIR TRAFFIC MANAGEMENT

IN

AN OLYMPIC CITY

By

John Guselli

JCG Aviation Services Pty. Limited.

SAFETY *and* EXPEDITION

AIR TRAFFIC MANAGEMENT IN AN OLYMPIC CITY

John Guselli MO 3675 - JCG Aviation Services Pty. Limited.

John Guselli was employed by Airservices Australia and its civil aviation predecessor organizations between 1972 and 2000. He was licensed as an Air Traffic Controller in 1974 and served in a wide variety of roles including that of Airport Manager, ATS Centre Manager, Operational Training Manager, and ATS Safety Manager. In 1998 he was appointed to the position of National Olympics Manager for Airservices Australia where he successfully coordinated all aviation elements of the Sydney 2000 Olympic Games He is currently Vice-Chairman of the ISASI ATS Working Group.

Introduction

On 23 September 1993, International Olympic Committee President Juan Antonio Samaranch uttered a sentence that will long be remembered in Australian folklore.
"AND THE WINNER IS SYDDDD..EEEE..NEEY"

Despite the fact that this announcement was made in Monte Carlo it had an immediate impact on the other side of the world. Many of the citizens of Sydney had waited up all night for this momentous news. Normally they do not need an excuse for a party but on this occasion it was perceived as a civic duty. The element of surprise within the words was even more pronounced because of the strong favouritism attributed to the Beijing bid.

In Monte Carlo the Honourable John Fahey, Premier of New South Wales, leapt to his feet, then into the air, as his state capital city was declared to be the host city for the 2000 Summer Games. The graphic image of his euphoria has been etched into the highlights of the Games. His leap of 1.2954 metres set a new Olympic record for a serving politician.

As the excitement subsided the mood changed to one of introspection. Sydney was like a dog that had been chasing a bus for some time. It had finally caught the bus! The question became "now what do we do with it?"

Following this announcement, the City of Sydney had 2547 days to prepare for the Opening Ceremony. To the average operational person in the aviation industry this represented more than enough time by any standard. This assumption was to become the first of many early mistakes that our aviation industry made from the outset.

Airservices Australia (AA) took a positive and early position with respect to the Sydney 2000 Games. As the national Air Traffic Management service provider it was acutely aware of the public scrutiny that usually came with any national event that associated with aviation. The initial response was provided from local AA management at the Sydney ATS Centre. This group was highly motivated and capable from the outset. The nuances of the required Olympic overlay became apparent in the early stages with the initial assistance of the US Federal Aviation Administration (FAA) and the working groups within the International Olympic Committee (IOC). Their experience of being there and doing it before would make the task much easier. That was the second assumption.

Increasing international interest led to AA determining that the Games ATM component required a national, as distinct to a state, overview. A manager was appointed and physically located in Sydney. This ensured a consistency in management and an overall point of coordination. A significant number of agencies were involved in the planning process. Agencies such as the Sydney Organising Committee for the Olympic Games (SOCOG), the Olympic Coordination Authority (OCA) and the New South Wales Police Service had been deeply immersed in all facets of Games planning from the outset.

The Aviation Plan

By any interpretation there was little surprise when the AA Olympic operational objectives were produced. They were simply to:

1. Optimise the throughput of Sydney Airport
2. Manage the increased demand at other Sydney basin airports and;
3. Manage the special-use airspace safely, securely and efficiently

The Operating Environment

Similarly the ground rules for the aviation overlay of the Games were quite simple. Australian aviation would operate to its standard procedures. For the Sydney Basin in particular this meant that

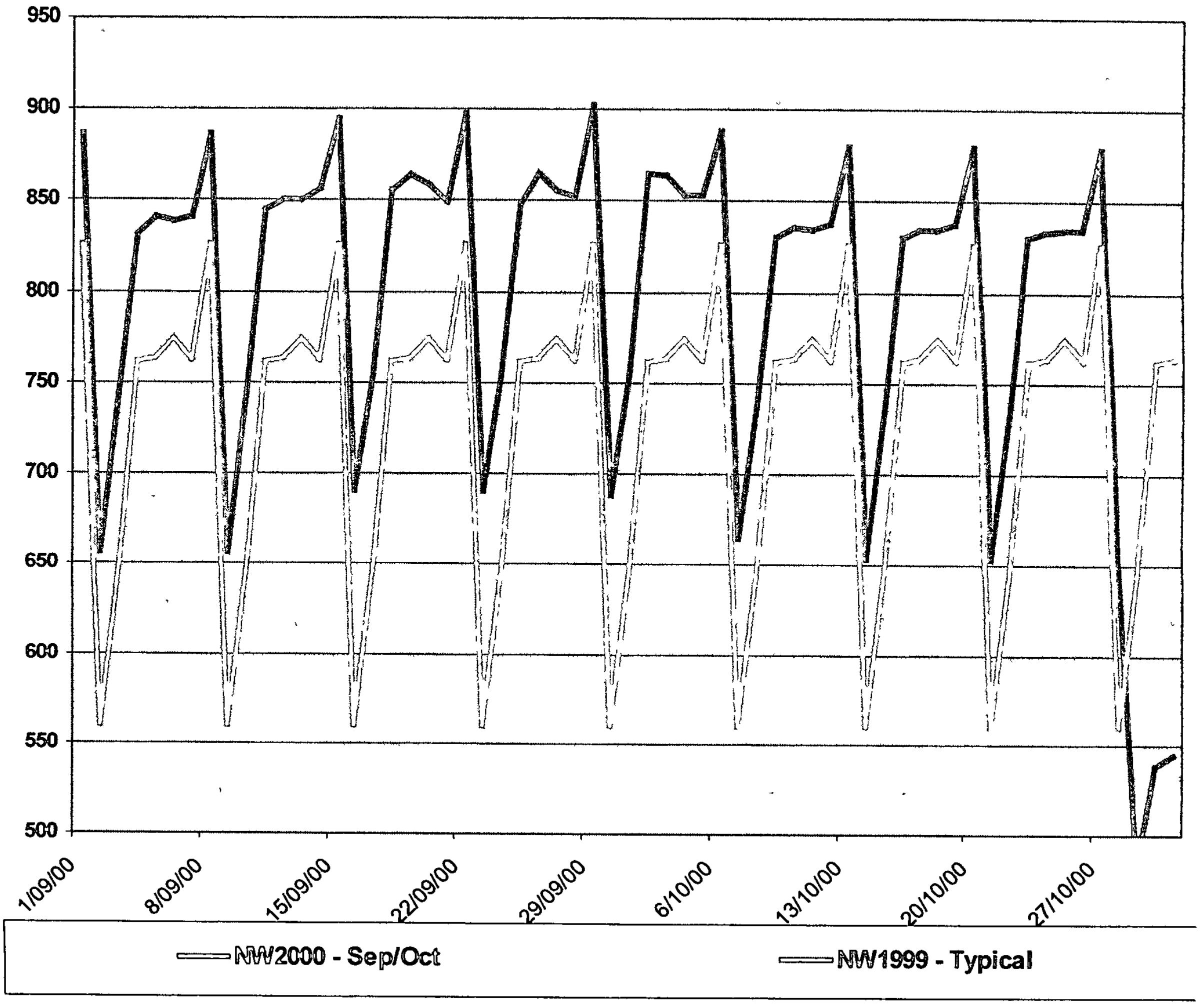
- The Sydney Airport Curfew Act would remain in place
- The Capacity Cap of 80 aircraft movements per hour would remain
- The Long Term Operating Plan processes would remain
- All environmental obligations would continue to be honoured

The Forecasting Process

The process in itself initially appeared quite straightforward. All that was required was to quantify the demand for air traffic services and then apply the resources to meet that demand. This seemed quite logical in 1993.
1997 saw staggering forecasts being produced almost on a daily basis. At one point it was estimated that around 50% of the worlds long haul air transport fleet would be on the ground in Sydney at approximately the same time. This could have been quite an achievement if it were not impossible.
The more rational approach commenced in earnest in 1998 and involved selective canvassing of airline alliances, corporate aircraft operators, and government agencies. The intelligence that was provided by this exercise was minimal. Like most things in aviation, an event two years into the future was really not worth getting excited about. General Aviation too was similarly uncommitted. The common theme at this point revolved around the fact that everybody would make their respective fortunes from the tourist trade. Another assumption!
It was only when the airline northern winter schedules were compiled that the picture became clearer. The Sydney Airport traffic predictions that existed on 31 December 1999 are displayed in the diagram below. They were a product of those airline schedules and were supplemented with previously allocated slots that existed at the time. They were the first tangible figures on which to base an ATM demand.
As a consequence of the lack of other detail Airservices Australia elected to plan upon a worst-case scenario in providing the necessary services.

SCHEDULED MOVEMENTS SYDNEY AIRPORT

1 August – 31 October 2000 (compared to 1999)



INCREASED TRAFFIC SYDNEY BASIN

Airport Infrastructure

Sydney (KSA) Airport

The potential demands imposed by increased traffic movements were a high planning priority for those agencies with airport exposure. The Sydney Airports Corporation Ltd (SACL) was actively involved in this process from an early stage. Their terminals and infrastructure had been upgraded enormously in the lead up to the Games. All of their efforts were intertwined with the ability of Airservices Australia to process aircraft through the Air Traffic Management system efficiently to and from their facilities

Additional and obvious airport based functions including Customs, Immigration, Foreign Affairs, Quarantine and Meteorology were similarly woven together as a cohesive team. A common theme that was embraced, related to the knowledge that many thousands of visitors to Sydney would form not only their first, but also their last impressions of Australia, at Sydney Airport.

Analysis of this traffic growth revealed a broad increase across the board from the 1999 baseline. From a strategic sense it was expected that a large amount of exchange would take place between Australian business travel and leisure travel associated with the Games In spite of this factor though there was a subliminal change occurring within the domestic travel market as a consequence of new entrant airlines. The traffic numbers were rising even without the overlay of the Games.

Bankstown Airport

The forecasting process determined a heavy demand for the use of Bankstown Airport. As the scheduled movements increased for Sydney so too did the operational realisation that corporate, charter and light freight operations would need to operate from Bankstown to minimise delay to their businesses

Bankstown Airport Ltd. (BAL) entered into an agreement with a major FBO to meet the handling and facilitation requirements predicted. This in turn led to the first real planning by a number of flying training organisations to curtail or relocate their operations during the Games period. The ATM service, thus affected, saw staff rosters prepared to provide 24-hour daily tower coverage.

Camden Airport

As the traffic demand at Bankstown increased it became apparent that the incompatibility of the Games related operations with the training activities had a potential to compromise safety. To mitigate against this the ATM service at Camden was increased to cater for additional demand.
Additional ATC staff members were imported into the Sydney Basin to assist in this capacity.

Hoxton Park Airport

Increased Sydney basin General Aviation (GA) traffic was assessed to have a consequent impact on the airspace usage patterns at both Bankstown and Camden airports Allied to this was a stated preference from a number of itinerant operators to use the "quieter airport". This fact, and the close proximity of three Games venues (Equestrian, Shooting and Mountain Bike) produced the decision to establish a GAAP control zone
This in turn led to the provision of a temporary control tower. This facility was salvaged from a depot in Brisbane, relocated to Sydney and refurbished to provide an excellent service. It has since become an important ATM contingency asset.

Airspace Management

From an ATS safety perspective, aspects of trunk route segregation from the Games related air activities became a major focus. This process drew significantly on the resources of the En-route Control centres in Brisbane and Melbourne.

Impacts of operations external to Sydney Airport were assessed for potential choke points. A significant effort was made to decongest routes that could limit capacity on major trunk routes. The Canberra – Sydney route was one such example where the potential for "day trip" traffic was suggested throughout the forecasting process.

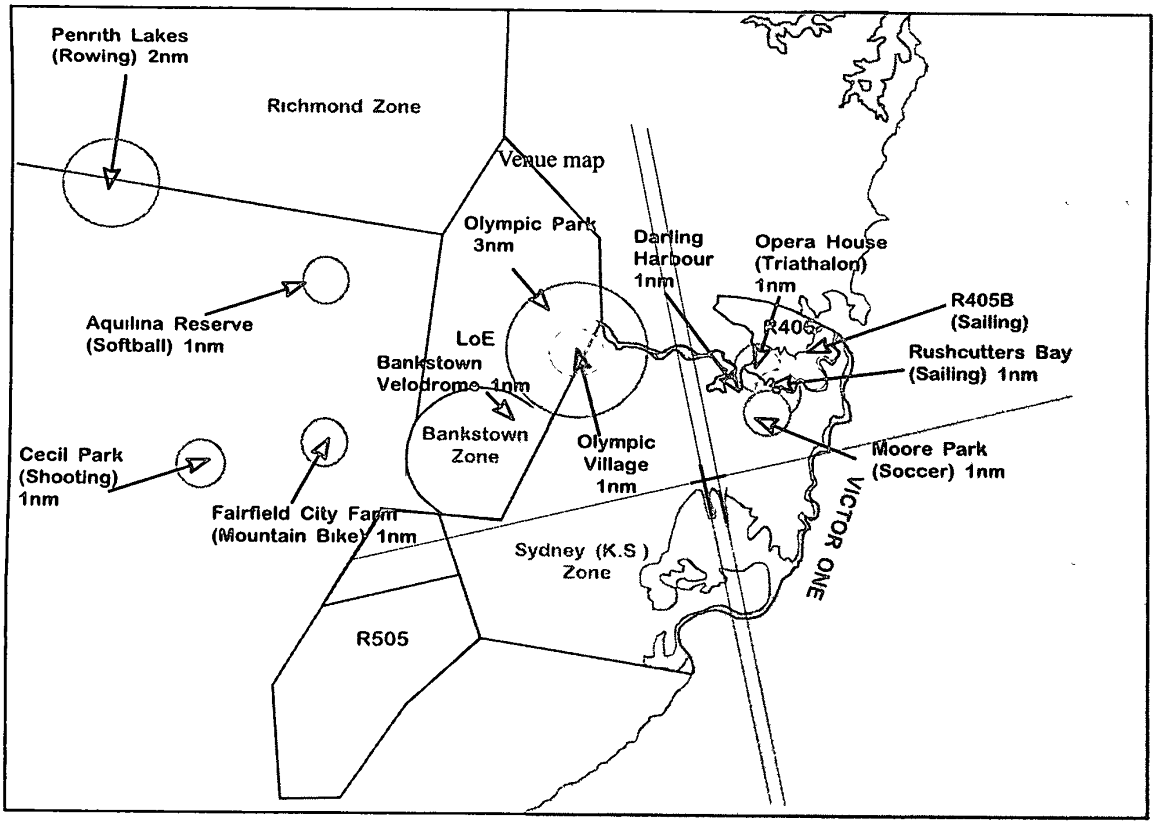
Wherever possible, rotary operations were excised from fixed wing considerations. This was done in full consultation with the rotary operators within the Sydney basin over a period more than 12 months prior to the opening ceremony. Cohesion within the rotary industry was at an all time high during the Games.

The existing Lane of Entry that enabled aircraft to transit between Bankstown and the north of Sydney was assessed as a threat to airspace integrity at an early stage. It had long been a contributory source of primary airspace violations. This fact and the proximity of the track to the location of the Olympic Stadium and Athletes Village led to an early re-alignment of the lane. The variation took aircraft on a more northerly heading, rendering airspace violations less critical to Sydney traffic.

Special Use Airspace

The award of the host city contract to the City of Sydney delivered significant obligations to Air Traffic Management in Australia. The right to a ***"quiet enjoyment of the Games"*** was paramount within that contract This obligation applied to each and every Olympic venue and of course, the Athlete's Village. This was a reasonable thought initially until the venues were plotted over the existing air routes!

The latent conflict of spectator aircraft, high powered corporate sponsorship commitments and "quiet enjoyment" led to the production of many new ATM procedures to cater for the needs of those operators accredited to utilise special use or "Olympic Venue Restricted Airspace".



The OCA issued this accreditation and became the Administering Authority for this newly created

airspace. Airservices took the lead role in designing, coordinating and promulgating this airspace and subsequently became the Airspace arbiter. It did so with the total support of the security agencies associated with the Games.
This was not an easy path in the beginning though. A consistently strong legal position was held by Counsel for AA that ultimately saw required the passage of legislation by the New South Wales Government to permit the "special use" airspace to be managed legally. This matter of legality was absolutely critical and one that could have been challenged, at short notice, and rapidly compromise the success of the 2000 Games. The Olympic Arrangements Act 2000 eventually carried fines of $250,000 for any unauthorised entry into any Olympic Venue Restricted Airspace.

OLYMPIC AVIATION SECURITY

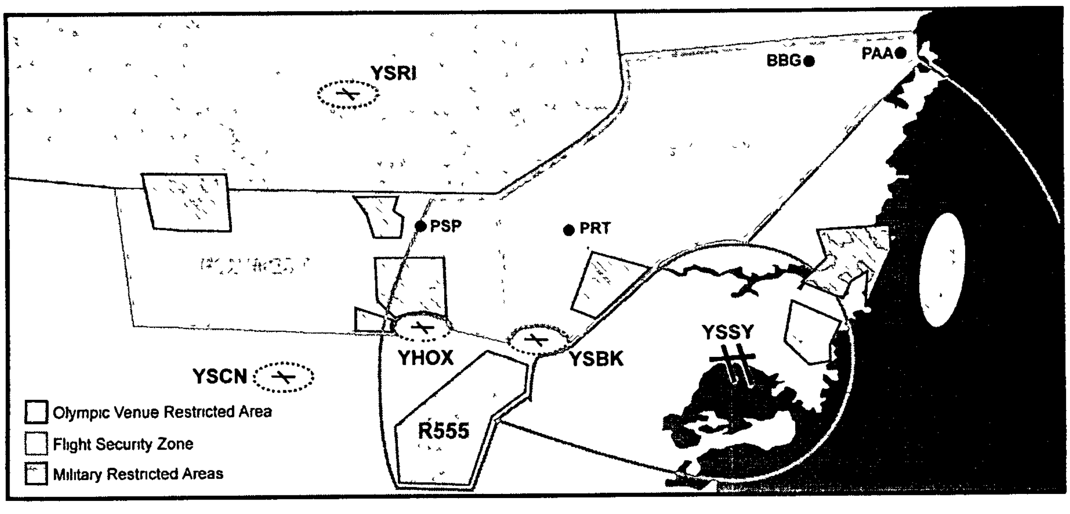
As an agency of the Host City, the New South Wales Police Service took the primary role in Olympic aviation security. Over seven thousand members of the Australian Defence Force (ADF) supplemented their effort. The ADF provided the real strength of deterrent opposition to any potential terrorism. Many of these personnel were in transit from an active Peace Keeping service in East Timor and had passed briefly through their home base on their way to a three-month deployment to Sydney.

Interim airspace requirements were delicately balanced between the "wishes" of the IOC and the reality of practical aviation needs within the Sydney Basin. This situation saw a blanket exclusion of any operation other than security or Sydney Olympic Broadcast Organisation (SOBO) aircraft operating within any defined "Olympic Venue Restricted Airspace". This immediately established conflict with a host of "ambush marketers" who saw the prize of a "golden egg" in Sydney.

Specialist advice from the security agencies determined a need for the establishment of a mechanism to monitor airborne traffic in the areas adjacent to Olympic Venues. Yet another unique situation arose whereby any non-scheduled aircraft, intending to fly though a "Flight Security Zone", had to provide minimal details to enable ATC to flight follow their operation Despite the unique nature of this process it was highly successful. All that was required of aircrew was pre-flight advice of callsign, destination and track. A simple VHF check call established the transaction.

Most aircraft operators expected observation from some form of civil ATC personnel. What they did not realise was that they were also being tracked by specialists at the Olympic Security Command Centre in central Sydney. Airservices Australia technical support personnel had skilfully provided contingency radar feed that enabled an independent monitoring capacity in the event of a security situation.

FLIGHT SECURITY ZONES SYDNEY 2000

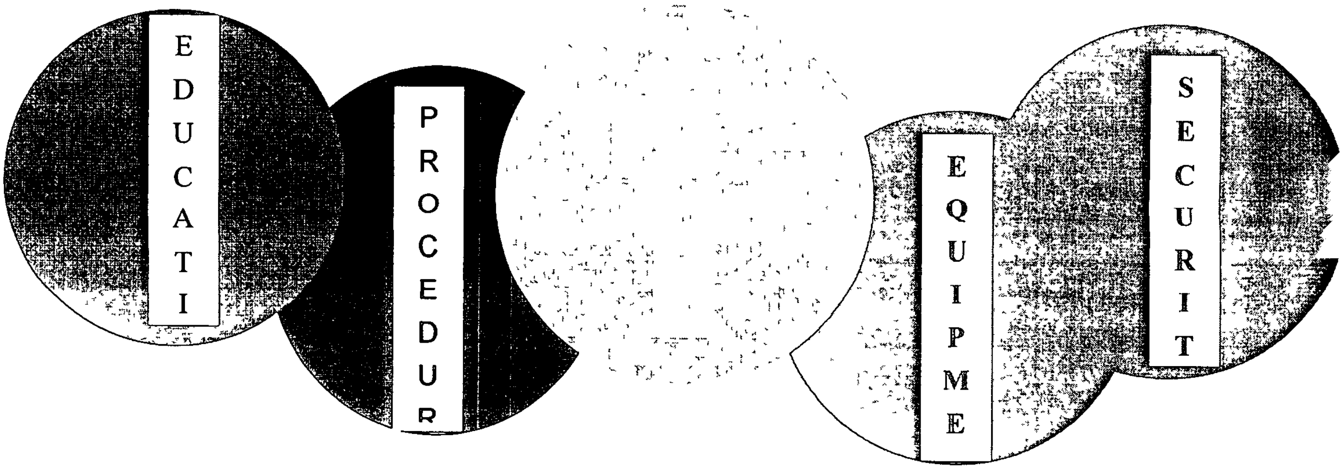


The Safety Process

If safety is the reduction of risk to the lowest acceptable level then it follows that all that was required for the Games overlay was to define that level. The difficulty of this premise, in an Olympic sense, was that the commitments made during the bid were randomly blended with a national preoccupation to deliver the greatest show on earth. This in turn led to a developing spirit of "can do" that was increasingly accepted by almost all within the aviation industry.
Failure was not considered to be a viable option.

The Australian aviation industry possessed an appropriate level of confidence in the existing structure. The focus therefore shifted to the additional and often unique demands generated by the Games as a consequence of the award of the Host City Contract from the IOC.
Through an exhaustive process of consultation, research and prediction these primary issues were determined for the Sydney Basin. Wherever possible they were quantified and listed for action as early as possible.

The unique Olympic ATM issues fell into five broad activity areas;



PEOPLE

The heart of any endeavour comprises people. The 2000 Games imposed a substantial workload for the ATM environment and this included all facets of the Airservices Australia service. At the front line were the controllers, firefighters and the senior management but immediately beside them were the technical and operational support functions. Underpinning these groups were the administrative support functions that were necessary to integrate all the processes.
In addition to the routine ATM services, Airservices Australia was required to provide the following.

- Additional operational staffing at several national facilities
- Liaison, Briefing, and Emergency response personnel
- New and unique procedures
- Additional hours of operation at existing ATC units
- Additional controller tools
- Continuous consultation with concerned parties
- Education and continued briefing for airspace users

- New ways of disseminating information
- Design, development and review of staff training for new elements
- Military liaison
- Increased supervision
- Provision of local accommodation for staff
- Enhancement of crisis management plans
- Provision for potential increase in counselling facilities
- Assurance to the regulator of the safety of the event
- Establishing a media centre
- Planning and consulting for, publishing and reviewing, new charts, instructions and procedures

EQUIPMENT

The current equipment was already highly reliable but the technical support structure delved even more deeply into contingency planning, spares holdings and calibration availability Any possible maintenance and inspection was completed well before the ramp up in traffic in August. This enabled a rapid response to critical areas of the network if required.
In addition, the technical support structure provided items of facility below in record time and with minimum complaint

- Additional Traffic management controls
- Restrictions on software system changes
- Provision for additional controller tools
- Establishment of chat frequencies
- Establishing common security priorities and response
- Assurance to the regulator of the safety of the event
- Changes to flight planning requirements
- Establishment of a temporary control tower and GAAP service at Hoxton Park
- A temporary radar sensor for the Sydney Basin at Cecil Park.
- Situation display equipment for Bankstown Tower
- A flow control radar display at Sydney for Bankstown Airport traffic
- Situation display at Olympic Security Command Centre

EDUCATION

The most critical deliverable aspect of the project was education of staff at all levels. Myriad stakeholders were equally educated in what became a series of continuous meetings.

- Additional routes
- Additional Air Traffic Control frequencies
- Additional tower establishment
- New procedures

- New air traffic management designs
- Additional Traffic management controls
- Provision for additional controller tools
- Continuous consultation with concerned parties
- Education and continued briefing for airspace users
- Restrictions on non-essential flights
- Restriction of airspace users including accreditation policy for OVRA
- New ways of disseminating information
- Design, development and review of staff training for new elements
- Military liaison requirements
- Increased level of security at Airservices facilities
- Ground management planning
- Enhancement of crisis management plans
- Assurance to the regulator of the safety of the event
- Changes to flight planning requirements
- Establishment of a temporary control tower and GAAP service at Hoxton Park
- Planning and consulting for, publishing and reviewing, new charts, instructions and procedures

PROCEDURES

As with the education elements so diverse were the changes that they required a continuing round of briefings, newsletters and high-level presentations to advise all of;

- Additional routes
- Additional Air Traffic Control frequencies
- Temporary control tower at Hoxton Park
- New air traffic management design
- Additional Traffic management controls
- Restrictions on TAAATS software system changes
- Provision for additional controller tools
- Education and continued briefing for airspace users
- Restrictions on non-essential flights
- Restriction of airspace users including accreditation policy for OVRA
- New ways of disseminating information
- Establishment of chat frequencies
- Consultation for enhancement of taxiways
- Ground management planning
- Provision for potential increase in counselling facilities
- Changes to flight planning requirements
- Establishment of a temporary control tower and GAAP service at Hoxton Park

- Planning and consulting for, publishing and reviewing, new charts, instructions and procedures

SECURITY

A significant and valuable linkage was formed between AA and the security agencies. A complete openness in the relationships enabled complex and classified information to be integrated into the required aviation outcomes. These matters were usually resolved in the most expeditious manner and free from the traditional rivalries between services This positive co-operation enabled areas like the helicopter lane along the Parramatta River, and adjacent to the Homebush Bay site to remain open throughout the Games period without a problem

Particular emphasis was placed on;

- Military liaison
- Review of contingency plans
- Increased level of security at Airservices facilities
- Enhancement of crisis management plans
- Restriction of airspace users including accreditation policy for OVRA

THE SAFETY OUTCOME

Right from the beginning of the project there was an enthusiastic co-operation from the Civil Aviation Safety Authority. As the national ATM regulator they elected to keep a watching brief on the whole of Airservices Olympic preparations. Their presence at many of the early major meetings enabled a speedy resolution to be obtained to issues that could quite easily have become enormous.

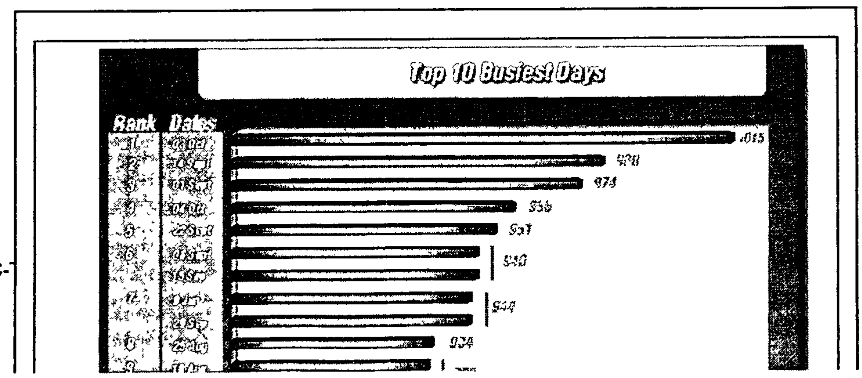
As the final ATM strategies were produced a comprehensive briefing was provided to CASA to enable the Airservices safety management processes to be thoroughly analysed prior to publication.

As the national provider of air traffic control and aviation rescue and fire fighting services, Airservices Australia played a vital role in contributing to the safety, efficiency and effectiveness of the 2000 Olympic and Paralympic Games.

Both Games resulted in large increases in air traffic movements through Sydney Airport in particular, but also throughout the entire National Airways System.

The following slide shows the Top 10 busiest days on record for Sydney.
Here was evidence of expedition – but was it safe?

ASC-



Firstly some background to the Airservices safety-reporting system. It has developed over the years to not only capture the base intent of the Australian Air Navigation Act 1920, but to also provide reporting to Airservices of elements that have been identified to combine in an error chain.

Often this data is relevant only to Airservices. However over the years we have also developed an electronic distribution system that presents Electronically Submitted Incident

Reports to ATSB and CASA at the same time our management is informed. This provides for timely advice to ATSB and CASA.

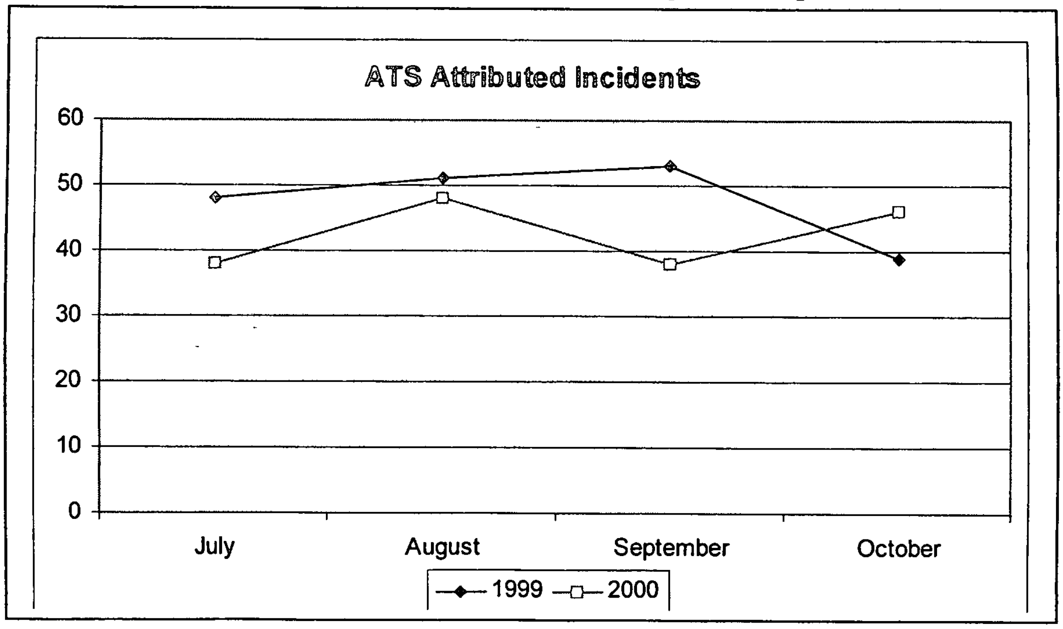
Airservices, ATSB, CASA and the Defence Directorate of Flying Safety are currently working together on a project to rationalise these reports. It should be noted that Airservices generates approx 70 - 80 % of incident reports that ATSB receive. The challenge here is to rationalise distribution and yet still keep the valuable information that is relevant to our organisation.

The reports are classified into 5 groups depending on assessed severity. They are also categorised for occurrence attribution. These include Air Traffic Service, pilots of Military aircraft, pilots of Australian registered aircraft, pilots of foreign registered aircraft.

NATIONAL ATS ATTRIBUTED INCIDENTS

Year	July	August	September	October
1999	48	51	53	39
2000	38	48	38	46

On face value these figures would tend to indicate that there was trend towards more incidents during the games period than during the same period in 1999.



It should be noted that comparative data before 1999 is not available and so this data is indicative and is probably not statistically valid considering the sample.

SYDNEY INCIDENT DATA FOR THE SAME PERIOD

Of 49 reported incidents for October **1999**, only 4 were attributed to ATS in Sydney.
Of 54 reported incidents for October **2000**, only 3 were attributed to ATS in Sydney.
Of the 3 incidents attributed to ATS, all were classified as "Not critical".
It is important to note that this does not reflect the whole of the aviation activity for the period as these figures do not include other activity in the airspace around Sydney such as entry to and exit from the Olympic Venue Restricted Areas.

What does it all mean?

Airservices committed significant resources to the Olympics. In answering the question of safety *versus* expedition, the reader must decide. The commitment of management and staff to make this event both safe and expeditious has not been discussed in depth Statistics alone do not truly provide the argument either way. The statistics do however indicate an improved safety position compared with the same period in 1999. By any standard Airservices contributed significantly to the safe, efficient and effective outcome of the Sydney 2000 Olympic Games.

APPENDIX 1

RUNWAY MOVEMENT DATA COMPARISON

Monthly average runway movements for Sydney between Jan. – Dec. 2000 were 25,695.

Jet Runway Movements 2000

Week Starting	RWY 07	RWY 16L	RWY 16R	RWY 25	RWY 34L	RWY 34R	Total
2 SEP	0	87	412	562	1517	937	3515
9 SEP	24	389	1179	443	1079	640	3754
16 SEP	31	254	795	242	1511	989	3822
23 SEP	107	395	1212	228	1221	725	3888
30 SEP	**106**	**229**	**853**	**480**	**1425**	**930**	**4023**
7 OCT	149	422	1203	117	1084	690	3665
14 OCT	216	356	1072	345	964	676	3629
21 OCT	206	296	981	246	1096	743	3568
28 OCT	312	248	810	70	1210	964	3614
4 NOV	308	569	1642	33	629	448	3629
11 NOV	188	144	464	87	1673	1065	3621
18 NOV	183	668	1819	56	581	407	3714
25 NOV	126	458	1186	105	1102	638	3615

Weekly runway movement figures for non-jet aircraft roughly aligned with the jet movements however there was a peak recorded for the week commencing 12 August of 2,521 movements.

附錄八

新加坡航空公司SQ006班機失事-飛航管制調查

Singapore Airlines Flight SQ006 Accident Investigation

AIR TRAFFIC CONTROL GROUP

By

Kuang-Tsang Chou,

Investigator, Aviation Safety Council, Taiwan, ROC.

Singapore Airlines Flight SQ006 Accident Investigation

Kuang-Tsang (K.F.) Chou, Investigator, Aviation Safety Council, Taiwan, ROC.

Before joining the Council, Mr. Chou had been working with Civil Aeronautics Administration, Taiwan for over 27 years. His last position at CAA was the Chief of Chiang Kai-Shek Approach.

History of Flight

On October 31, 2000, at 2317 Taipei local time, Singapore Airlines Flight SQ006, a Boeing-747-400 with registration number 9V-SPK, crashed on a partial closed runway during takeoff roll. Heavy rain and strong winds from typhoon "Xiang Sane" prevailed at the time of the accident. SQ006 was on a scheduled passenger flight from Chiang-Kai-Shek (CKS)International Airport, Taiwan, to Los Angeles International Airport, California, U.S.A. The flight departed with 3 pilots, 17 flight attendants, and 159 passengers aboard.

The aircraft was destroyed by its collision with construction equipment, runway construction pits on Runway 05R and by post impact fire. The tail section of the fuselage, the engines and landing gear separated from the rest of the aircraft. The forward and mid sections of the fuselage and the wings were totally destroyed by the fire. But the tail section only sustained slight damage.

On August 31, 2000, Civil Aeronautics Administration, Taiwan issued a NOTAM indicating that a portion of the Runway 05R between Taxiway N4 and N5 was closed due to work in progress from September 13, 2000, to November 22, 2000.

The pilots commenced duty on October 30, 2000, in Singapore, for the scheduled Singapore→Taipei→Los Angeles→Taipei→Singapore trip sequence. They completed the Singapore→Taipei sector on October 30, and arrived at the hotel in Taipei around midnight and stayed at the hotel until departure for the airport on the evening of October 31, 2000.

At 2035, the 3 pilots departed the hotel to CKS Airport and reported for duty at 2155. SQ006 had 3 pilots on board: one Captain and one First Officer with another First Officer as Relief Pilot. Captain was the pilot flying and conducted taxi and takeoff.

At 2307, after pushback from gate, SQ006 commenced taxiing via Taxiway SS, turned north and entered Taxiway WEST CROSS, and then turned left to Taxiway NP proceeding in a southwest direction.

At2315, just before reaching the end of Taxiway NP, SQ006 received takeoff clearance for Runway 05L. The pilots acknowledged the takeoff clearance for Runway 05L. The aircraft made a right turn from Taxiway NP into Taxiway N1 and continued the right turn onto Runway 05R.

At 2316, after a 6-second hold, SQ006 commenced takeoff roll from Runway 05R. Approximately 41 seconds later, it collided with the concrete jersey barriers, 2 excavators, 2 steamrollers, a bulldozer, an air compressor cart, and a pile of metal reinforcement bars on Runway 05R, between Taxiways N4 and N5.

At 1517, CKS Airport Control Tower signaled the emergency bell to the fire station after seeing explosions. Fire was seen along the takeoff path of the aircraft. There were 123,800 kilograms of Jet A1 Aviation fuel on board the aircraft. The fire brigade initiated the emergency response and informed Tao-Yuan County's Fire Fighting Action Center and Emergency Medical Service Center. The first fire engine began discharging its chemical extinguishing agent at the accident site within approximately 3 minutes after the alarm. The fire was very intense at the forward and mid sections of the wreckage. The tail section fire was less intense and was brought under control by the fire fighters. Heavy rain, low visibility and strong winds prevailed at the time of the accident. The fire-fighting group used a total of 2,300 gallons of chemical and 40,000 gallons of water during the fire fighting process.

A temporary command center was established at the accident site in a large passenger transportation vehicle The security system established by the Aviation Police Service Center consisted of a combination of aviation police, local county police and military police. Nine fire engines and 4 ambulance vehicles from CKS Airport, and another 34 fire engines and 54 ambulance vehicles from the local area were used.

All injured passengers and crewmembers were gathered at terminal building and sent to the local hospitals. Passengers that sustained burn injuries were sent to fire and burn intensive care center of the local hospital.

Seventy-nine passengers and 4 flight attendants were fatally injured. Thirty-five passengers and 4 flight attendants sustained serious injuries in this accident.

ATS related factual information

Air Traffic Control

ATC Procedures (see Appendix 3-02)

The Standard Operating Procedure of CKS Control Tower requires the ground controller to inform the aircraft by using phraseology "PART OF AIRPORT IS INVISIBLE FROM TOWER, TAXI SLOW DOWN WITH CAUTION." in maneuvering area when visibility drops to below 2000 meters.

There are also procedures for controller to issue progressive taxi / ground movement instructions when:

1. Pilot/operator requests.
2. The controller deems it necessary due to traffic or field conditions, e.g., construction or closed taxiways.
3. As necessary during reduced visibility, especially when the taxi route is not visible from the tower.

The progressive taxi instruction was not issued for SQ006.

Airport Surface Detection Equipment (ASDE)

The airport is not equipped with an ASDE though the control tower has been requesting for the installation of such radar system since 1994.

CAA has the budget to purchase two ASDEs in 2001. The date to commission the ASDEs has been scheduled in December 2004.

Airport Information

General

CKS Airport is 16.7 nautical miles west of Taipei city.

The layout of CKS Airport is shown in the following Figure 10-1.

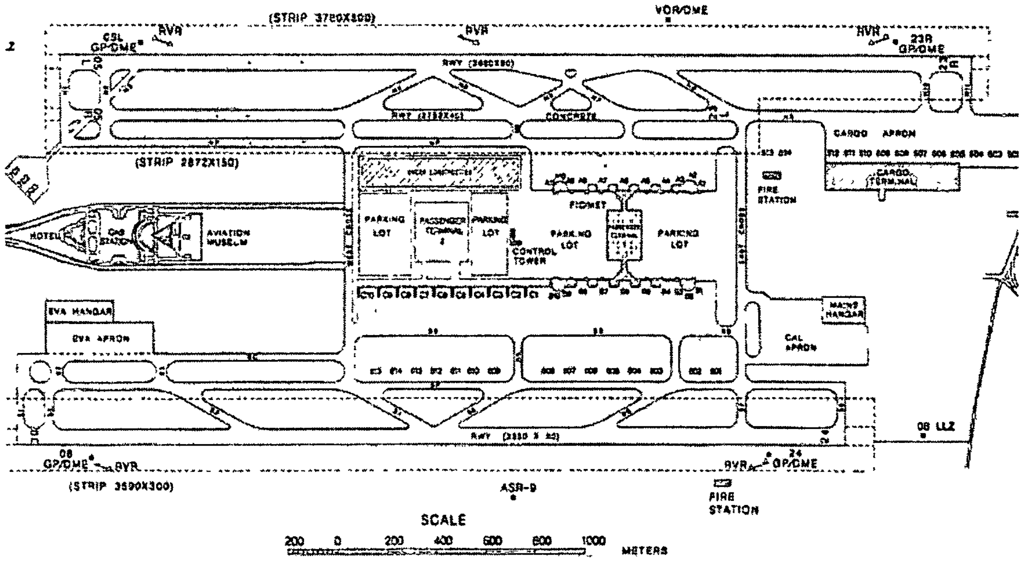


Figure 10-1 Layout of Chang Kai-Shek (CKS) Airport

Runway Physical Characteristics

CKS Airport has three parallel runways, viz. 05L/23R, 05R/23L and 06/24. Runway 05L/23R is for Category II ILS. Runway 06/24 is for Category I ILS. Runway 05R/23L is a non-instrument. It can be used at pilot's request for take-off only, provided the cloud ceiling is at least 200 feet and visibility is at least 1,600m. Simultaneous use of Runway 05R/23L and Taxiway NP will not be approved if the crosswind component is more than 22 knots (dry runway) or 17 knots (wet runway). Based on the AIP, Aircraft can take off from Runway 05L/23R above RVR of 200m.

The physical characteristics of Runways 05L/23R and 05R/23L, as published in the Taipei FIR Aeronautical Information Publication (AIP), are summarized in the following table10-1:

Table 10-1 Physical characteristic of runway 05L/23R and 05R/23L

Runway Designation	Dimensions (m)	Swy dimensions (m)	Cwy dimensions (m)	Strip dimensions (m)
05L/23R	3,660 X 60	60 X 60	300 X 300	3,780 X 300

05R	2,752 X 45	Nil	300 X 180	2,872 X 150
23L	2,752 X 45	120 X 45	300 X 180	2,872 X 150

Runway 05R/23L is separated from Runway 05L/23R by 214 m.
The marking, lighting and signage layout of threshold area at Runway 05R and Runway 05L including Taxiways N1 and NP, are shown in Figure 10-20.

__Taxiway Physical Characteristics__

The taxiways are: NP, NS, N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, West Cross and East Cross.

The width of taxiway NP is 30 m with 11m for each shoulder. Other taxiways are designed with 35m width and 11m shoulders. NP is the taxiway parallel to Runways 05R/23L (non-instrument runway) and 05L/23R (instrument runway). The separation distance between the center line of Taxiway NP and Runway 05R/23L is 110 m, while that with Runway 05L/23R is 324 m.

__Location of Runway-Holding Positions__

CKS Airport has two runway-holding positions for runway 05L end of the runways, one each at N1 and N2; both are 120m away from 05L runway centerline. Another runway-holding position is marked on Taxiway NP, which is 76m toward N1 taxiway centerline. The locations of the runway-holding positions are shown in the Figure 10-2:

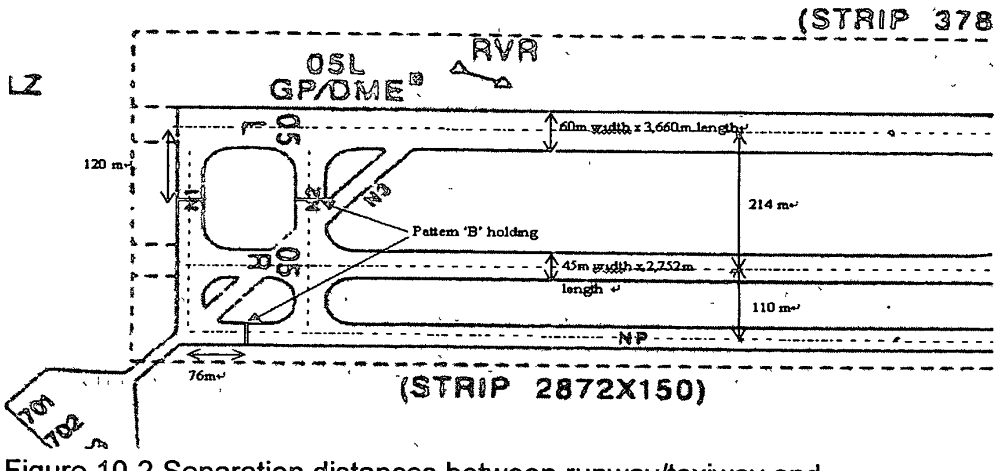


Figure 10-2 Separation distances between runway/taxiway and runway-holding positions

__Runway Holding Position Marking__

Runway holding position markings pattern 'B' are provided at the various holding positions identified in Section 1.10.4. (See Figure 10-3 and 10-4)

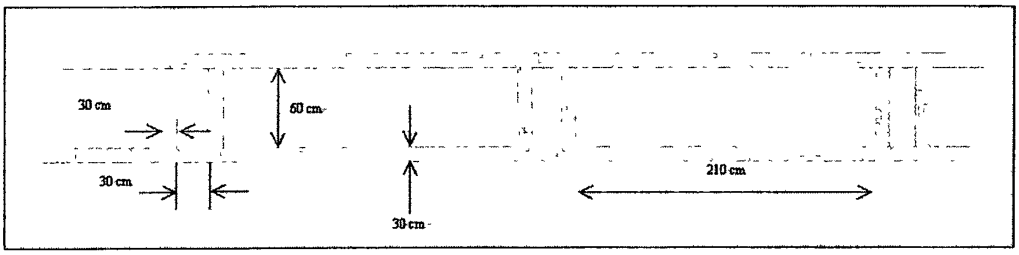


Figure 10-3 Dimensions of runway holding position marking at CKS Airport

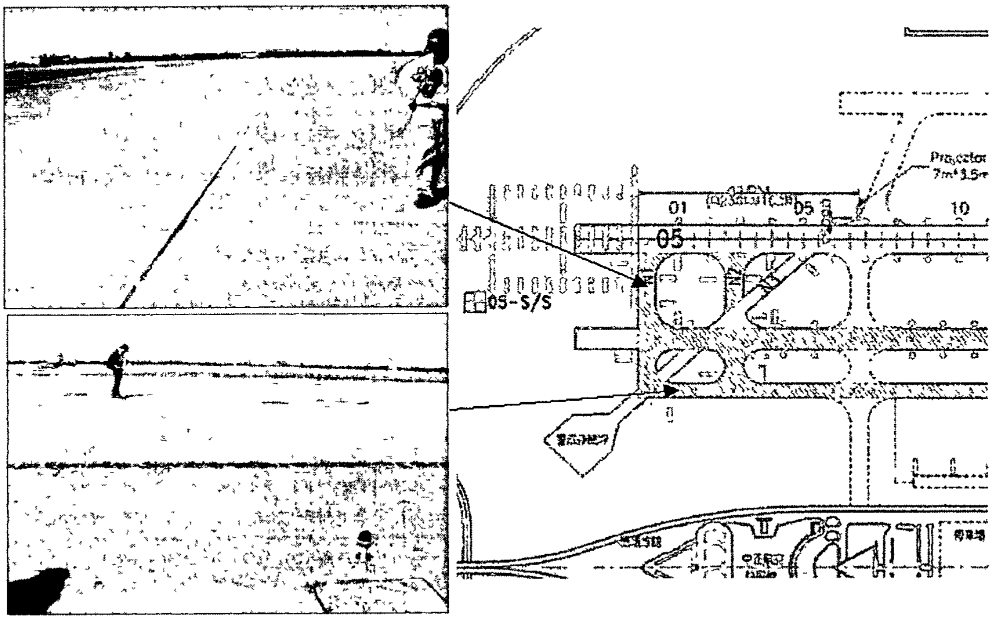


Figure 10-4 Runway holding position markings provided at N1 and NP taxiways

Intermediate Holding Position Marking

Intermediate holding position markings are not provided at taxiway intersections at CKS Airport.

Threshold Marking

Threshold markings are provided for each of the Runways 05L, 05R, 23L and 23R. The photographs and sketches in Figure 10-5 and 10-6 show these markings on the runway and their measured dimensions. Runway 05R/23L threshold marking is same as the 05L/23R threshold marking.

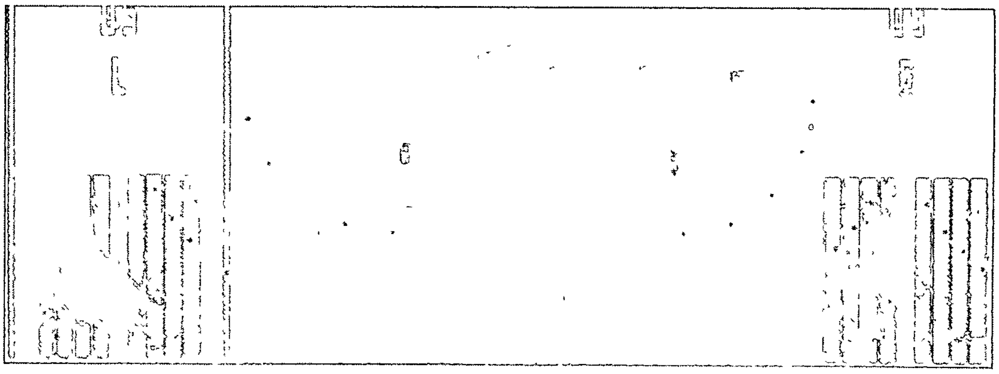


Figure 10-5 Runway 05R, 05L Threshold Markings

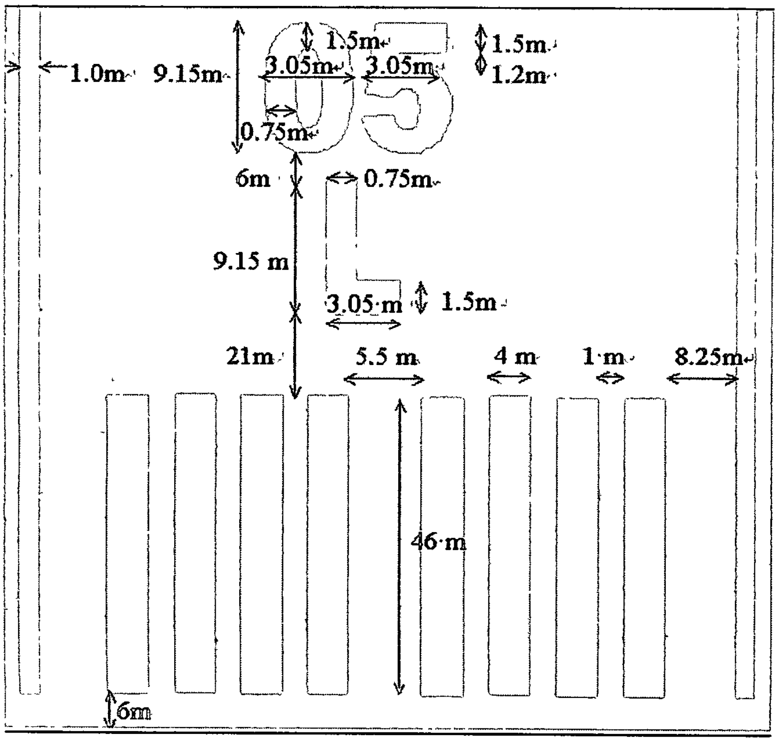


Figure 10-6 Dimensions of Threshold and Runway Designation Markings at Runway 05L(Not to scale)

Taxiway Center Line Marking

Generally, yellow taxiway centerline markings of 20cm width are provided at CKS Airport. However, a segment of the straight portion of the taxiway center line marking on Taxiway N1 providing guidance in the direction of the entry point to Runway 05L was missing. This missing segment of the taxiway center line marking was located between the end of the curved portion providing lead-in guidance from Taxiway NP to Taxiway N1 and the end of the curved portion of the taxiway center line marking providing lead-in guidance from Runway 05R/23L to the northern part of Taxiway N1. Reference is made to Figure10-7 and10-8 and the figure shown in Figure 10-20.

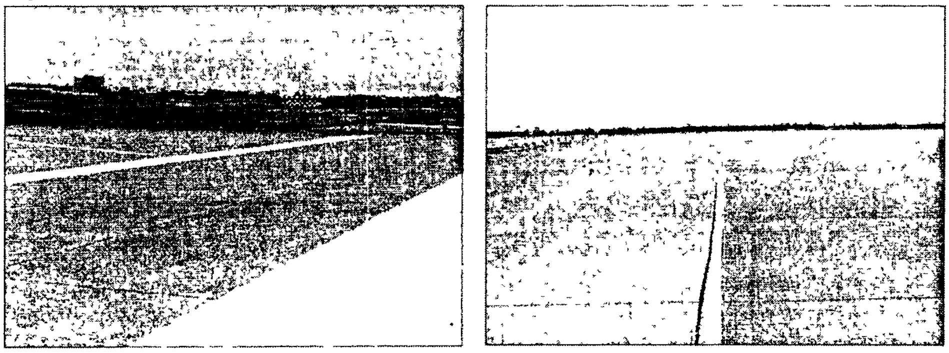


Figure10-7 Taxiway center line marking leading into Runway 05L

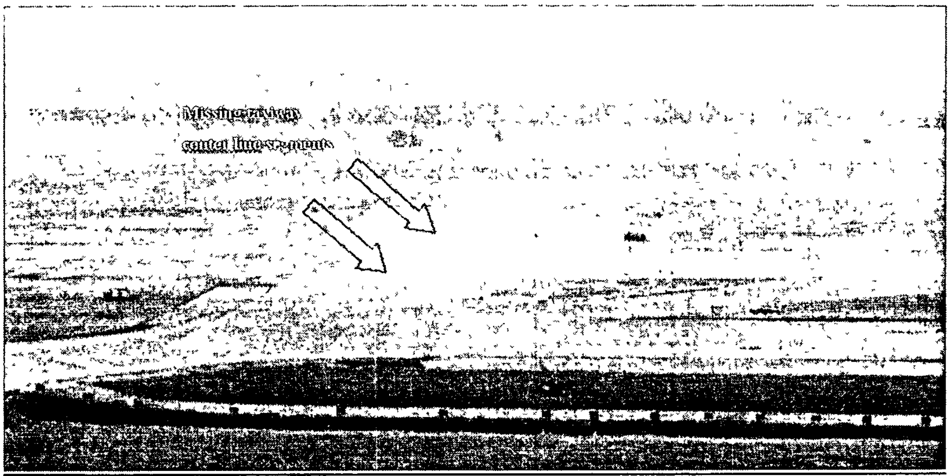


Figure 10-8 Taxiway centerline markings at the vicinity of Runway 05L and 05R threshold areas

Runway Lighting

The runway lighting system are shown in Table10-2

Table10-2 General list of Runway 05L and 05R lighting system

Facility	Runway lighting circuits in use
Runway 05L/23R	Approach lights(white, CATII with red side row barrettes) Runway centerline lights(white/red) Runway edge lights (white/yellow) and end lights(red) Touchdown zone lights(white) Threshold lights(green) PAPI(white/red) Taxiway edge lights (blue) at runway/taxiway

	intersections
Runway 05R/23L	Runway edge lights (white/yellow) and end lights(red) Taxiway centerline lights(green) Taxiway edge lights (blue) at runway/taxiway intersections

Runway edge lights

Bi-directional high intensity runway edge lights are provided for both Runway 05L/23R and Runway 05R/23L at CKS Airport. These are spaced at between 55-60m apart. These lights are both of identical make and model (Crouse Hinds L-862 elevated and L-852 inset, FAA specification) for either runway. The lamps used on the elevated runway edge light fittings are found to be 6.6A/T4Q/CL/2PPF and Philips 6372/200W/6.6A/8L. It is observed that several of the inset bi-directional runway edge lights for each runway are either missing (e.g. along Runway 05R/23L across N2 taxiway), or incorrectly installed in that the orientation of the light windows are aligned away from the direction of the runway (i.e. pointing in directions other than along the runway length). The Figure 10-9 and 10-10 show the runway edge light installations at Runway 05L/23R and 05R/23L.

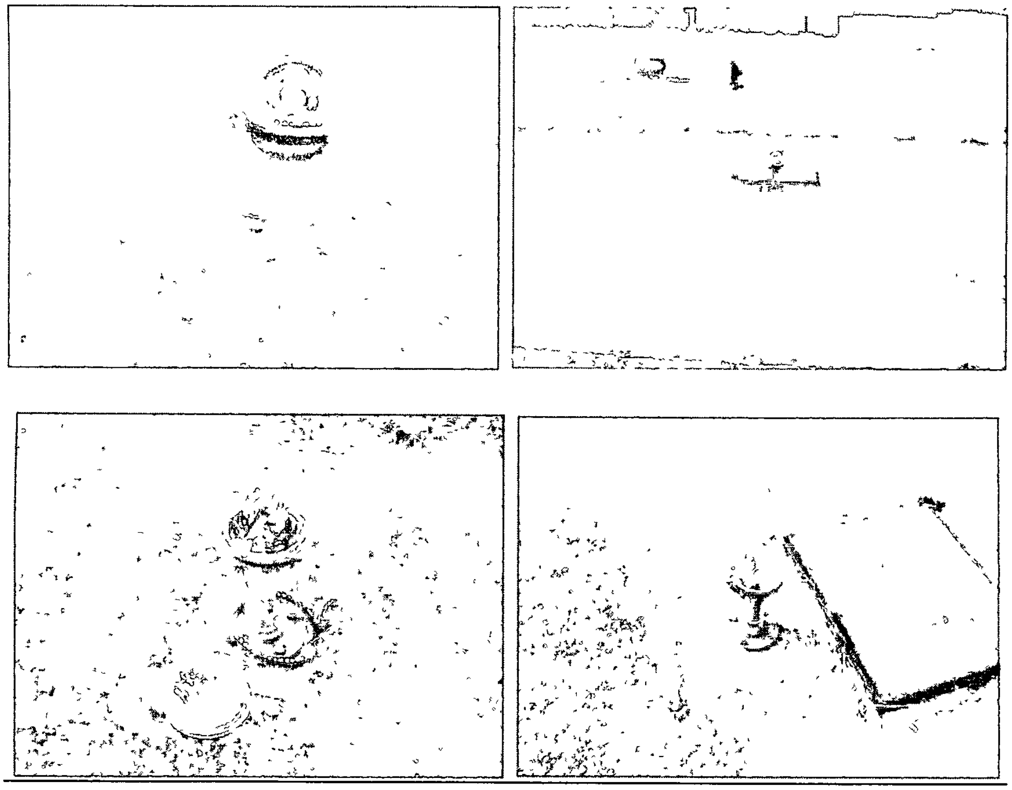
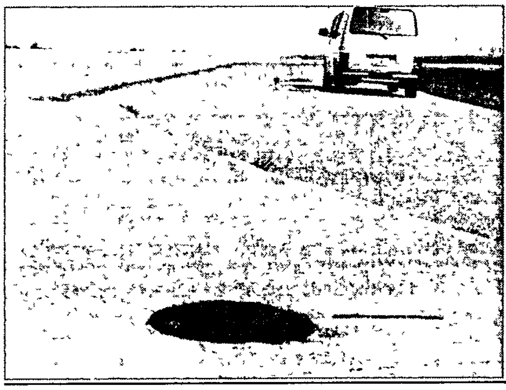


Figure 10-9 Runway 05L/23R and Runway 05R/23L (bottom right) edge lights



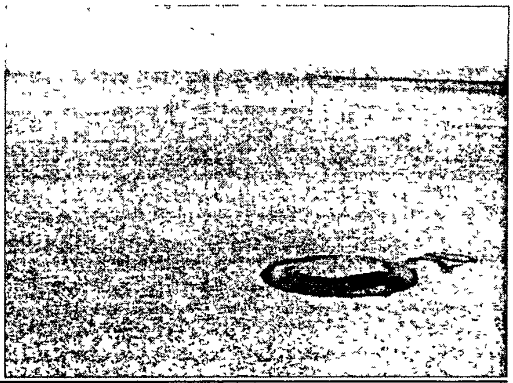
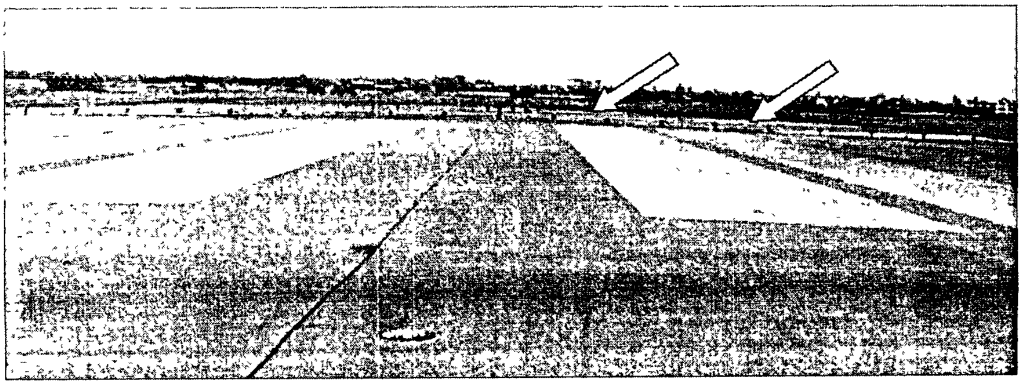
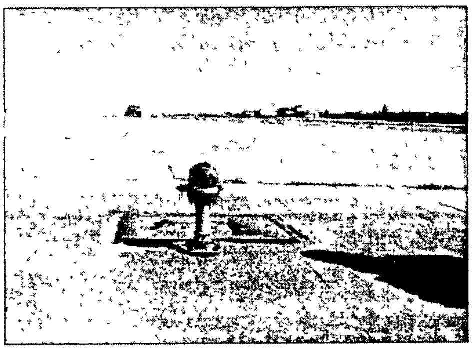


Figure 10-10 Incorrectly oriented inset runway edge lights (L-852) for Runway 05L/23R (left) and 05R/23L (right)

Runway End lights

Runway end lights are provided for Runway 05L/23R and 05R/23L at CKS Airport. There are 8 runway end lights at each location. These are linked to the runway edge light circuits and therefore share the same activation button from the Control Tower. The runway end lights are located symmetrically about the runway centerline as shown Figure 10-11.



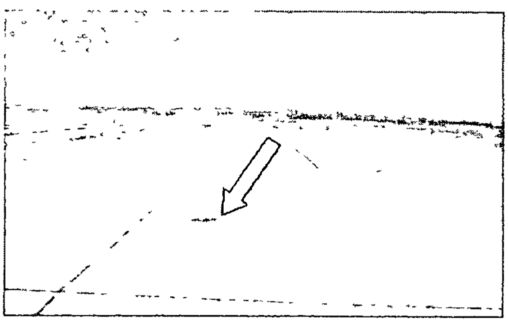


Top:
Runway edge lights at the 05L end of Runway 05L/23R
Left:
Rear view of elevated Runway 05R/23L end light fitting

Figure 10-11 05L and 05R runway end light

Runway Center Line Lights

High intensity runway centerline lights (L-850A 200W) are provided for Runway 05L/23R but not for Runway 05R/23L. These lights are fixed lights showing variable white from the threshold to the point 900m from the runway end; alternate red and variable white from 900m to 300m from the runway end; and red from 300m to the runway end. They are spaced at 15m apart, and offset by 60cm from the runway centerline.(see Figure 10-12)



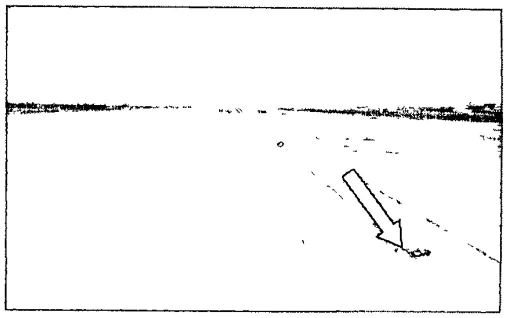


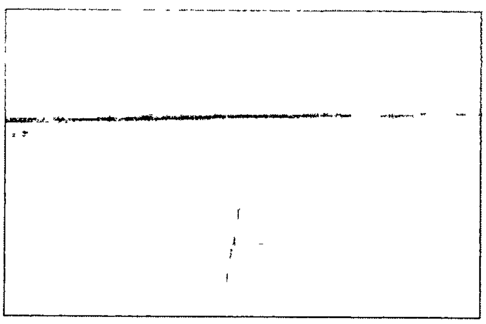
Figure 10-12 Runway05 Center Line Light

(Left: Red runway centerline lights near the runway end at 05L

Right: White runway center line lights at the commencement of Runway 05L)

Stop bar Lights

Stop bars are not provided at CKS Airport (see Figure 10-13).



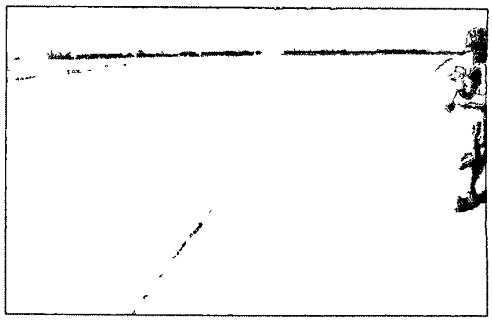


Figure 10-13 Entry taxiways into Runway 05L/23R at N1 (top left and bottom right) shown without stop bar light protection

Runway Guard lights

Runway guard lights are not provided at CKS Airport.(see Figure 10-14)

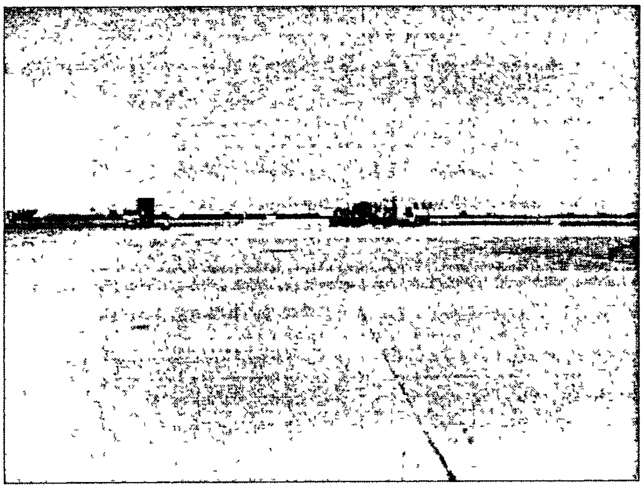


Figure 10-14 View of entrance into Runway 05R/23L from taxiway N1 (picture taken during site survey)

Taxiway Center Line Lights

Taxiway centerline lights (L-852, FAA specification) are provided on all taxiways at the north part of the airport. The southern part of the airport is not equipped with taxiway centerline lights. At exit and entry taxiways, these centerline lights also extend into the runway up to the runway centerline area. Taxiway centerline lights are also provided along the centerline of Runway 05R/23L (No runway center line lights are installed). These lights are found to be installed at varies distances from the taxiway centerline, e.g. 0.6m, 1.2m and 1.6m. On straight sections of taxiways, the centerline lights are found to be spaced 30m apart, while taxiway centerline lights on curved segments are at 7.5m spacing. On the curved taxiway sections, the taxiway centerline light fixtures are identical to those used along straight sections. All taxiway centerline lights are bi-directional and emit green light. There are no alternate green/yellow taxiway centerline lights on exit taxiways to demarcate the limits of the ILS sensitive area. The lamps used for taxiway centerline lighting are rated at 65W. (see Figure 10-15)

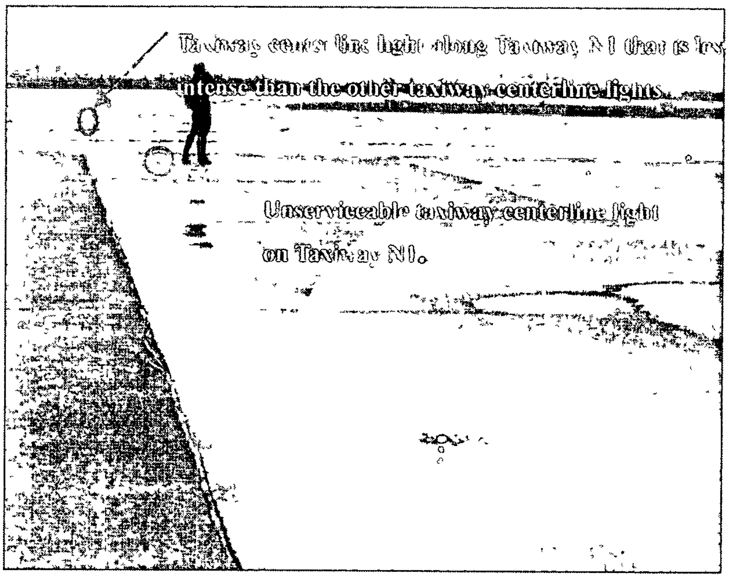


Figure 10-15 Configuration of taxiway center line lights Installed around Taxiway N1 (picture taken during site survey)

For an aircraft taxiing along Taxiway NP, the spacing of the green taxiway center line lights on the striaght portion of txiway NP is 30m As it turns right into Taxiway N1, the spacing of taxiway center line lights along the curved section is 7.5m up to the point of tangency with the Taxiway N1 center line. For aircraft taxiing onward:

(a) into Runway 05R, the spacing of taxiway center line lights along the curved section from this point is again, 7.5m up to the point of tangency with the Runway 05R center line. Beyond that, the spacing of green taxiway center line lights are 30m along the Runway 05R/23L.

(b) towards Runway 05L, there are 4 taxiway center line lights are provided along the straight segment of Taxiway N1 up to the Runway 05L holding position. These taxiway center line lights are located at a distance of 30m, 55m and 116m respectively from the point of tangency (where the curved taxiway center line marking from Taxiway NP meets Taxiway N1).

During site survey(on Nov 4, 2000), it was noted that the first taxiway center line light after the point of tangency was unserviceable while the second light was less intense than the other lights. (See Figure 10-13)

Taxiway center line light fittings installed along curved segments are identical with those provided for the straight segments (see Figure 10-16). Taxiway center line lights along the curved segment are required to have a toe-in angle of 15.75 degrees.

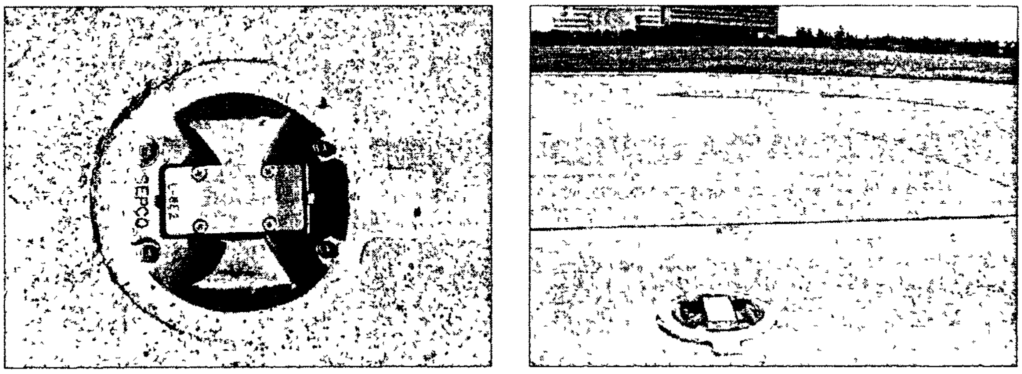


Figure10-16 Taxiway centerline light installed a curved taxiway section with straight bi-directional light windows (picture taken during site survey)

Airfield Lighting Control and Monitor

Circuit Interlocking

Runway 05R-23L was primarily used as a standard taxi-route and as such provided with green taxiway centerline lights. Other than having green taxiway centerline lights, Runway 05R is also provided with high-intensity runway edge lighting, runway threshold/end lights. No interlocking capability exists to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting.

As can be seen from Figure 10-17 of the runway and taxiway lighting control panel located in the Control Tower, individual pushbuttons are provided to switch on/off different airfield lighting circuits. These pushbuttons are hardwired directly to relevant'Constant Current Regulators located directly below the Control Tower, thus turning on/off the lights for the respective circuits. No form of electromechanical interlock or computerized control was implemented to prevent the simultaneous operation of both runway and taxiway lighting on Runway 05R/23L. A turning knob is provided for each of these circuits to enable the selection of different intensity levels for the airfield lights.

The ATC controller will turn on the taxiway lights when runway 05R/23L is used for taxi only. If the pilot request to use runway 05R/23L for takeoff and the weather and operation conditions permit, the ATC controller will turn on the runway 05R/23L edge lights.

For operations as a runway, the runway 05R edge lights must be on and the 05R taxiway centerline lights must be off. In addition, nighttime operations would require taxiway NP centerline lights to be on as well.

Based on the lighting control system diagram given in figure 10-19, the centerline lights on taxiway NP and the same switch controls centerline lights on runway 05R for each of the three different zones. Therefore, it does not seem possible to establish a single lighting configuration that would allow for night operation of runway 05R. That is, it is not possible to select the taxiway NP centerline lights on while selecting the runway centerline lights off simultaneously.

The ATC procedures provided in Mandarin state that taxiway NP and runway 05R may not be used concurrently, however, they do not appear to provide a specific procedure to turn select the taxiway lighting off once the airplane is positioned on runway 05R.

Figures 10-18 and 10-19 provide explanation on typical airfield lighting circuit switching function on one typical section of the control panel.

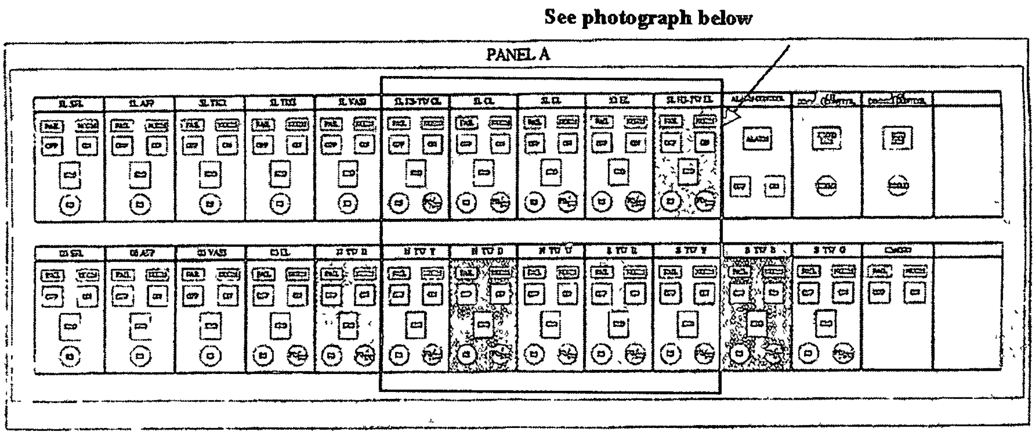


Figure 10-17 Drawing showing the layout of the airfield lighting Control panel located in the Control Tower

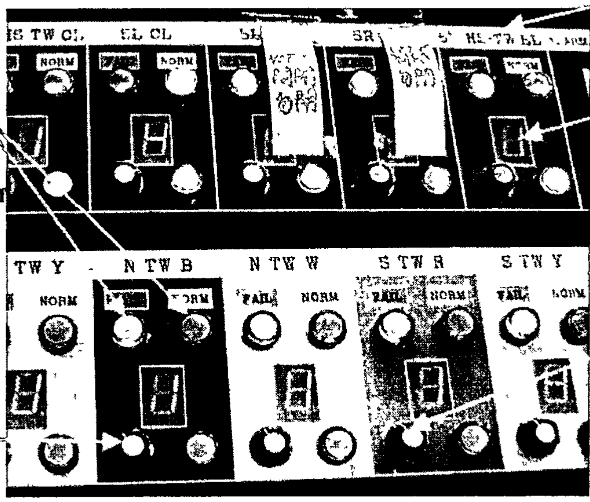


Figure 10-18 Section of airfield lighting control panel
(picture taken during site survey)
(One of 2 identical panels located in CKS Airport Control Tower)

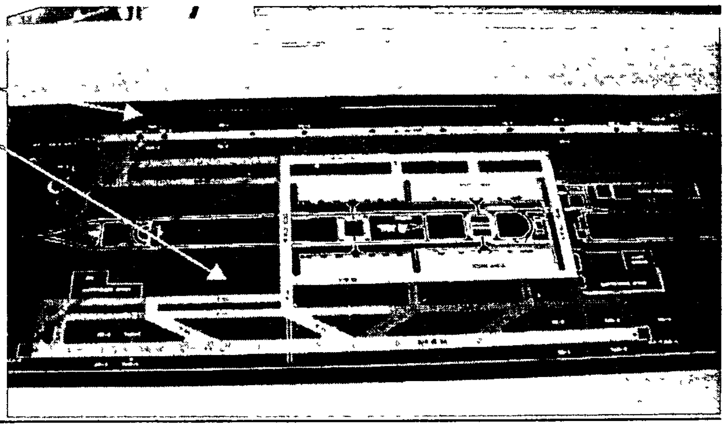


Figure 10-19 One of two airfield lighting mimic panel located at CKS Airport Control Tower
(picture taken during site survey)

Circuit Monitoring

The monitoring of airfield lighting system serviceability is implemented through hardwiring relay contacts from Constant Current Regulator to indicate the status for the related circuits. This provides feedback on the status of entire circuits. There is no monitoring of individual lights, or percentage of unserviceable lamps for any circuit. A simple hardwired electromechanical relay control and monitoring system is used at CKS Airport. As illustrated in previous section, the normal or failure status for each lighting circuit is presented through 2 corresponding indicator lamps on the control panel in the Control Tower. Feedback on intensity selection is displayed via a 7-segment LED module for each circuit.

There is also no system of data logging to register on hard or soft media the actual status of the airfield lighting circuit and the selected circuits in use at any time. The only form of logging indicating actual status of any airfield lights was found on a computer record of the Runway 05L/23R RVR system. The runway edge lights of Runway 05L/23R was recorded by the RVR System to provide an input parameter for calculation of RVR values presented to the Control Tower. The record showed that the Runway 05L/23R edge lights were selected at intensity level 3 during the time of the SQ006 occurrence. There was no record of the on/off status of any other airfield lights, including those on Runway 05R/23L.

Mandatory Instruction Signs

Mandatory instruction signs (L-858, FAA specification) are provided at CKS Airport. The location and inscription of these signs around Taxiway N1 are shown as Figure 10-20.

Mandatory signs, installed at entries to runways, are of white inscription on red background. These signs are of the internally illuminated type, and are around 1.1m heights. The nearest edge of these sign is around 20m from the nearest taxiway edge.

The mandatory instruction sign installed on the left side of Taxiway N1 at approximately 54m before the center line of Runway 05R threshold shows the runway designation "5R-23L"(see Figure 10-21).

The mandatory instruction sign installed on the left side of Taxiway N1 at approximately 75m before the center line of Runway 05L shows "CAT 2"(see Figure10-22). The mandatory instruction sign installed on the right side of taxiway N1 at the same distance before the center line of Runway 05L threshold shows "5L-23R|N1"(see Figure 10-23). The inscriptions on this combined runway designation (white lettering on red background) and taxiway location (yellow lettering on black background) sign has a white rectangle encircling the runway designation sign and a yellow rectangle encircling the taxiway location sign. The above 2 signs are located after the holding position for Runway 05L and not collocated with runway holding position marking.

For an aircraft entering Runway 05R from the southern side of Taxiway N1, the runway designation sign showing "N1|5R-23L" is located at 54m before the runway centerline and is not collocated with the runway holding position along Taxiway NP. For an aircraft entering Runway 05R from the northern side of Taxiway N1 (i.e. exiting from Runway 05L), the runway designation sign showing "N1|5R-23L" is located at 75m before the runway centerline and is not collated with the runway holding position.

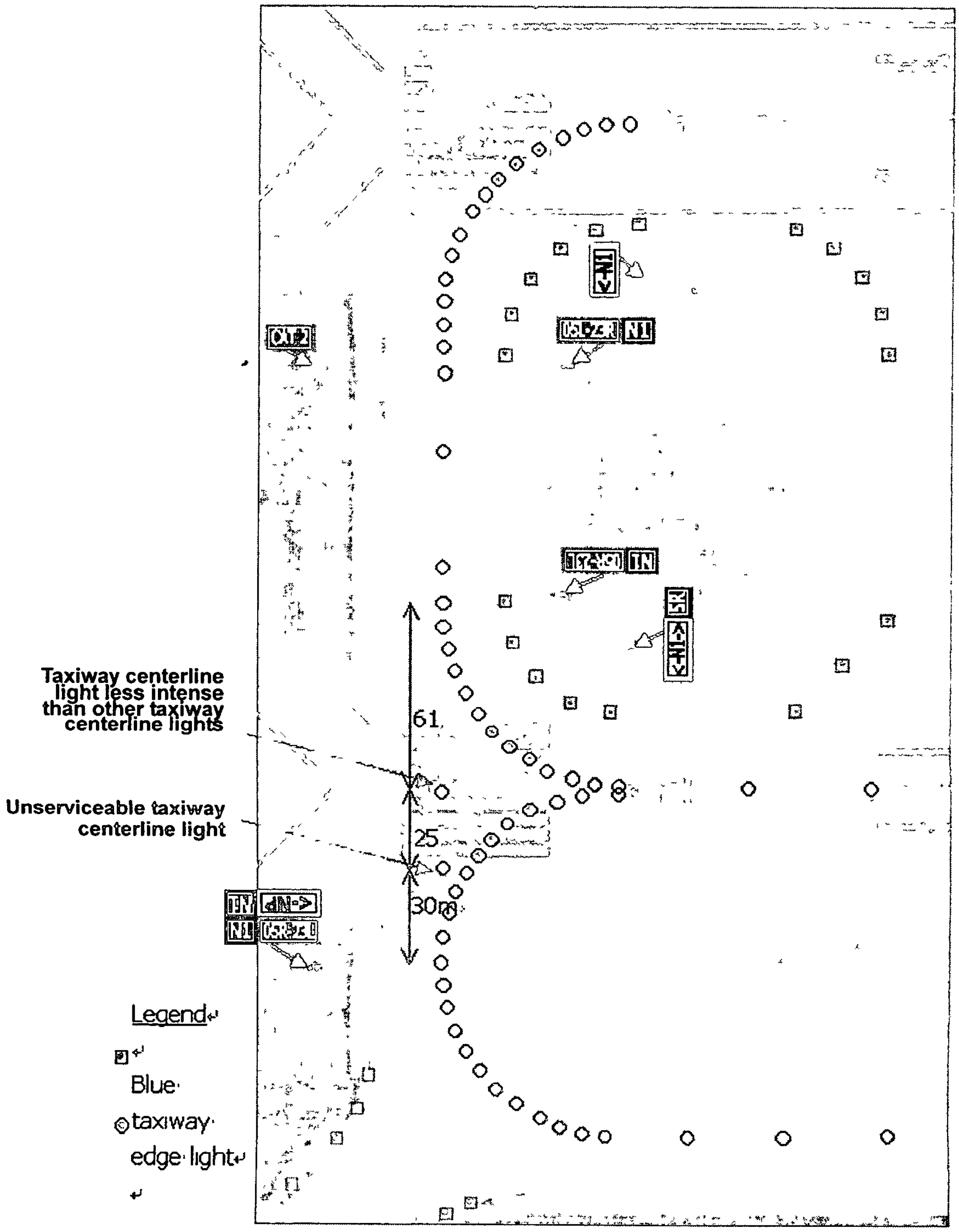


Figure 10-20 Aerial picture showing runway and taxiway markings, lights and signs at the threshold areas of Runway 05R and Runway 05L
(picture taken during site survey)

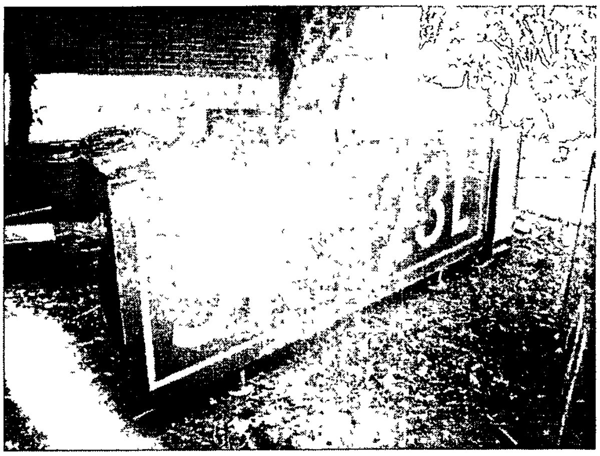


Figure 10-21 Closed-up view of mandatory runway designation sign removed from Taxiway N1 before Runway 05R/23L

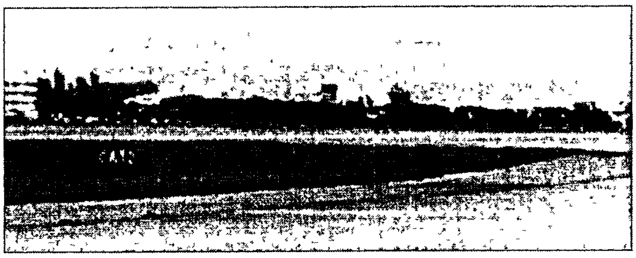


Figure 10-22 Mandatory CAT II sign found only at the left side of N1 taxiway leading to Runway 05L/23R

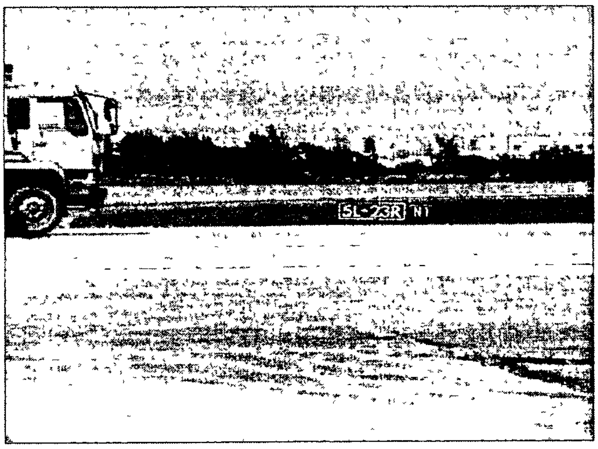


Figure 10-23 Mandatory runway designation sign found only at the right side of Taxiway N1 leading to Runway 05L/23R

Visual Aids for Denoting Restricted Use Areas

Background

Since 13 September 2000, Runway 05R-23L has been closed for take-off due to on-going construction works in the middle portion of the runway between Taxiways N4 and N5; however, the remainder of Runway 05R-23L and Taxiways N4 and N5 remained available for taxiing operations (NOTAM A0606).

CAA /ROC initiates projects to improve airfield facilities. This could arise from requests from internal departments or through consultation with users / airport operators. For example, the need for two additional Rapid Exit Taxiways at Runway 05L/23R was suggested by the CKS Control Tower (under ANWS) based on their operational requirements.

CKS Airport Management (Ground Operations Department) chairs a bimonthly meeting involving the Airport Operators Committee (airlines representatives), concessionaires, and government agencies such as Customs etc. CKS Flight Operations section and Maintenance & Engineering section are represented at the meeting too. Other CAA departments / sections such as ANWS, CAA headquarters and CKS cargo section may attend the meeting from time to time, whenever necessary. The meeting discusses issues on airport operations and facilitation matters. During this meeting, airport operators / users may give suggestions on improvements to the airport / airfield.

Improvement works in the airfield are budgeted by CKS Airport or the Aerodrome Engineering Division, depending on the cost. Once approved, the project is contracted to private contractors but supervised by the Maintenance & Engineering section Safety regulations are given to the contractor.(Refer to Appendix 4-1)

Airport users are notified of airfield works that affect operations through the issuance of NOTAM. NOTAM is issued by the Flight Information Center of the airport, which is under the ANWS. Request for issuance of NOTAM is coordinated between the Maintenance & Engineering section, Flight Operations section and the Control Tower. Operational requirements are taken into account prior to determining closure periods for different phases of the project.

Obstacle Height Control for Machinery Working on Runway 05R/23L

The construction site on Runway 05R/23L is located about 200 m from the centerline of Runway 05L/23R. Based on the 1:7 slope of the Runway 05L/23R transitional surface, the height limit at the edge of the runway is about 5.92m (see Figure 10-25).

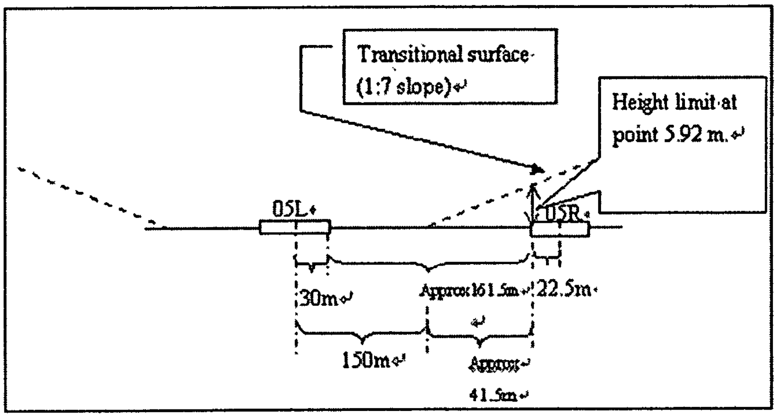


Figure 10-25 Cross Sectional View of the Runways and 05L Transitional Surfaces

The construction equipment (2 excavators, 1 bulldozer, 2 vibratory rollers) parked on the middle of Runway 05R/23L on 31 October 2000 range from 1.5m to a maximum of 2.75 m height and do not exceed this height limit. As such, they do not constitute obstacles to Runway 05L/23R transitional surface, as specified in Annex 14, Volume I, Chapter 4.

Closed Runways or Taxiways, or parts thereof

No closed markings were provided close to the construction area along Runway 05R-23L.

Unserviceable Areas

The closed portion of the runway is provided with barriers consisting of Jersey blocks made of solid concrete. (see Figure 10-26,10-27) The dimensions of these concrete blocks are 0.8m high, 1m long and 0.15m to 0.45 m wide. The blocks are marked with yellow, orange or a mix of yellow and black stripes. In addition, battery-powered, flashing red unserviceable lights spaced at a distance of 2 to 5m are provided on top of the blocks for nighttime use.

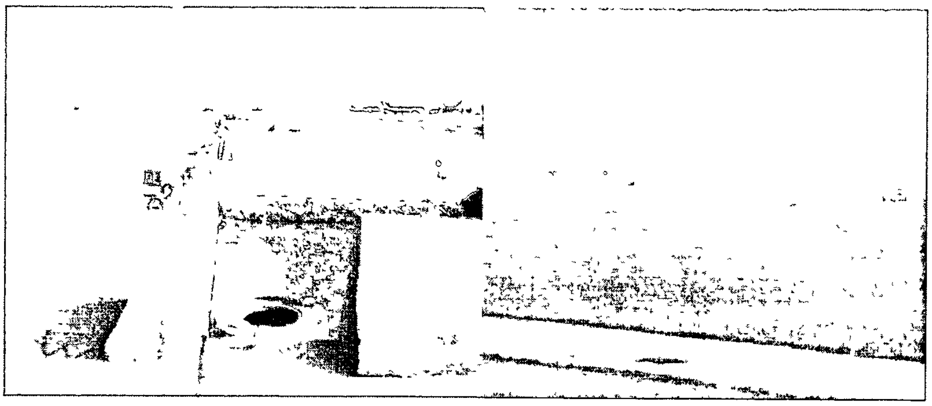


Figure 10-26 Closed work area along Runway 05R/23L and closed taxiway work area viewed from Runway 05L/23R

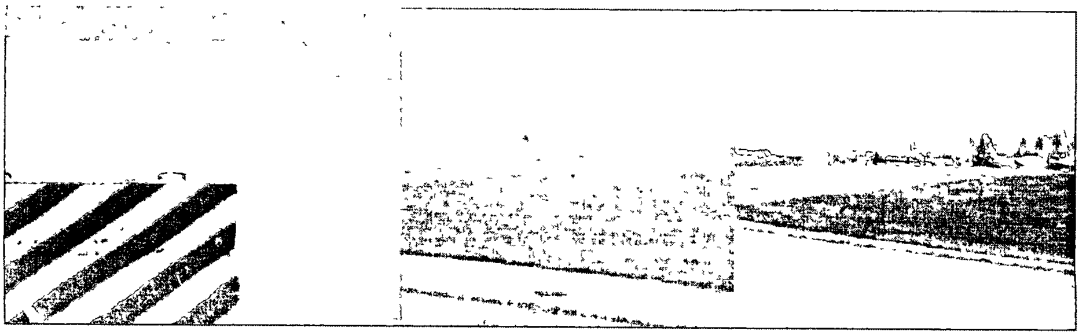


Figure 10-27 Jersey blocks of different colors used on the airfield at CKS Airport

Surface Movement Guidance and Control System (SMGCS)

An SMGCS provides guidance to, and control or regulation of, an aircraft from the landing runway to the parking position on the apron and back again to the take-off runway, as well as other movement on the aerodrome surface. It comprises an appropriate combination of visual aids, non-visual aids, procedures, control, regulation, management and information facilities.

The visual aids components of CKS Airport's SMGCS (i.e., markings, lighting and signs) have been described in previous sections of this report. There is no detailed Airport SMGCS plan for low visibility operations provided at CKS Airport.

Guidance on the use of visual aids in a SMGCS is contained in Appendix 4-43.

Airfield Lighting

Air Navigation and Weather Services (ANWS) maintain airfield lighting system. ANWS has a maintenance unit stationed at the Control Tower of CKS Airport.

The unit comprises ten staff – six supervisors and four artisans. They are scheduled on two three-man shifts round the clock. (Refer to Appendix 4-3)

ANWS maintenance staffs inspect the airfield lights twice a day, once in the morning (0900 – 1100 hours) and once in the afternoon (1300 – 1500 hours). They need to coordinate with the Control Tower for an available time slot to enter the airfield. Faults are recorded in the morning and rectified in the afternoon on the same day. No night maintenance is conducted on the runways and taxiways. In addition to the daily checks, ANWS has weekly and monthly checks for different airfield lights that require attention to greater detail. (Refer to Appendix 4- 3)

Airfield Signs

Like airfield lighting, technical specifications of airfield signs are provided by the Air Navigation Facilities Division of CAA ROC. ANWS installs the airfield signs according to these specifications. According to CAA ROC, ICAO standard and recommended practices are adopted.

ANWS also maintains the airfield signs of CKS Airport. Inspection of airfield signs takes place concurrently with inspection of the airfield lights daily. Blown fluorescent tubes are replaced on the same day. In addition to the daily checks and maintenance, there are weekly and monthly preventive maintenance scheduled which could involve dismantling of signs for off-site repairs. (Refer to Appendix 4-3)

Airfield Markings

The CKS Maintenance & Engineering section is responsible for maintaining airfield markings. Repainting of runway markings coincide with removal of rubber deposits on the runways. Repainting of airfield markings in other areas is carried out once every two to three years. (Refer to Appendix 4- 3)

Black Outline Markings

Only apron centerline markings are outlined in black for added conspicuity. Taxiway centerline markings and holding position markings are not outlined at CKS airport.

Conversion of Runway 05R/23L to Taxiway NC

CAA is aware that use of Runway 05R will affect safety as well as the operations of the cargo apron. According to them, coordination is complicated; ATC has to ensure no aircraft is pushing back at the cargo apron before it can allow any aircraft to take off at Runway 05R. As such, Runway 05R/23L is rarely used in recent times. According to the AIP, Runway 05R/23L can only be used for take-off under VFR conditions (visibility > 1,600m). The last time Runway 05R/23L was used at least before 3 months ago under VFR conditions.

Furthermore, the presence of Runway 05R/23L imposes an obstacle limitation surface on the Air Cargo Complex, which limits the future redevelopment of the Air Cargo Complex. The height of structures under the future Phase 1 and Phase 2 of the Air Cargo Complex (to be built at the present cargo parking bays) will be limited to about 16.42 m only. This will not be sufficient to cater for future capacity demand. It is understood that CAA had engaged a company, AirPlan Consultancy, in 1995 to amend its master plan, including the planning of future runways and taxiways. AirPlan Consultancy had since 22 November 1999 been looking into converting Runway 05R/23L to a taxiway, which will alleviate the height limit of the Cargo Complex.

The decision to decommission Runway 05R/23L and to convert it to a taxiway was made by CAA ROC in 17 February 2000. This proposal was submitted to the Ministry of Transportation and Communications, and approval was obtained to proceed with the necessary works on 11 April 2000. Between April 2000 and October 2000, there were several planning meetings between the various Divisions of CAA ROC. It was decided to officially convert Runway 05R/23L to a taxiway on 1 November 2000. Necessary follow up works include removal of Runway 05R/23L markings and painting of taxiway markings (to be undertaken by the CKS Airport Maintenance & Engineering section) as well as changing of signs / lights (to be undertaken by ANWS). An AIP Supplement (A007C015/00) was issued on 3 October 2000 to inform of the change with effect from 1 November 2000. However, conversion of Runway 05R/23L to Taxiway NC was subsequently postponed as the necessary painting works and procurement of signs was not complete. The AIP Supplement was cancelled by a NOTAM dated 23 October 2000. After the conversion works, the closed

Runway 05R/23L was re-opened as Taxiway NC on 1 February 2001.

<u>Improvements made by CAA after the accident</u>

附錄九

管制員如何處理航空器緊急情況

"MAYDAY, MAYDAY, MAYDAY"

by

Dr Sue Baker

Head of Human Factors

and

Mr Ian Weston

Head of Safety Investigation and Data Department

Civil Aviation Authority

United Kingdom

"MAYDAY, MAYDAY, MAYDAY"

A Joint Paper by Dr Sue Baker, Head of Human Factors and Mr Ian Weston, Head of Safety Investigation and Data Department, United Kingdom Civil Aviation Authority

Words that not only everyone in aviation recognises but which are also universally accepted to denote that a state of emergency exists. The International Civil Aviation Organisation's Manual of Radiotelephony (Doc 9432) details Distress and Urgency Procedures and clearly shows that the word MAYDAY spoken at the start (of a message) identifies a distress message which indicates "a condition of being threatened by serious and/or imminent danger and of requiring immediate assistance". There is little doubt that while we might not all be able to quote the definitions word for word and that some within the aviation industry would query phraseology standards across the world, the use of the word MAYDAY is guaranteed to bring an added concentration and a rise in adrenaline levels to all those who hear it in an operational context. Or is it?

In the late 1980s and early 1990s the United Kingdom's Air Traffic Services Investigation Section (ATSI) of the Civil Aviation Authority's Safety Regulation Group was becoming increasingly concerned that the use of the phrase by pilots was not receiving the response that it deserved from UK civilian air traffic service units. This was particularly concerning as, certainly in our opinion, UK air traffic controllers' standards are at least as high as their colleagues around the world. Although the incident occurred over 10 years ago, lessons learnt from it are still leading to new enhanced safety initiatives in ATC operations and therefore, we believe, worthy of being brought to the attention of ISASI in 2001.

ATSI is a dedicated air traffic accident and incident investigation section that has been in existence for over 30 years and is tasked with conducting independent investigations of all UK air traffic incidents. Funded by the Civil Aviation Authority, it also provides, by invitation, expertise to the United Kingdom Air Accidents Investigation Branch to assist their enquiries into Air Traffic Control and Air Traffic Management issues. Similar assistance has been given to many other States. In the late 1980s a decision was taken to enhance this type of investigation by including a human factors professional into the ATSI team. This was especially apposite the UK's statistical evidence indicates that human error is apparent in some 95% of the ATC events that are reported in the UK.

The ATSI experience showed that not only were there a number of poorly handled aircraft emergencies being experienced but also, and possibly more concerning, a number where MAYDAY calls had not been heard by the controller although they had been clear on the associated frequency recordings when they were studied by the investigators. Whilst the numbers of such incidents formed only a small percentage of the total received and had not led to any aggravation of the outcome, the potential effects on flight safety were obvious. Efforts were concentrated on determining the cause of the problem to ensure that an appropriate solution could be found. However, at all times the maxim that the primary concern was to enhance flight safety and not to attribute blame was employed.

These concerns came to a head early in June 1990 when an accident occurred to a BAC One Eleven over Didcot, Oxfordshire, UK. Delegates to the conference may well recall the event which has been discussed at a previous ISASI Seminar.

The accident occurred during a scheduled flight from Birmingham to Malaga, Spain. With 81 passengers, four cabin crew and two flight crew the aircraft took off from Birmingham International Airport at 0720 hours and, having been transferred to the of London Air Traffic Control Centre (LATCC), was cleared to Flight Level (FL) 140. A number of radar headings were given until the flight was instructed to continue a radar heading of 195°M and cleared for a further climb to FL230. The co-pilot had been the handling pilot during the take-off and, once established in the climb, the commander was handling the aircraft in accordance with the operator's normal operating procedures. At this stage both pilots had released their shoulder harness, using the release bar on the buckle, and the commander had loosened his lap-strap.

At 0733 hours as the cabin staff prepared to serve a meal and drinks, and, as the aircraft was climbing through about 17,300ft pressure altitude, there was a loud bang and the fuselage filled with condensation mist. It was at once apparent to the cabin crew that an explosive decompression had occurred. The commander had been partially sucked out of his windscreen aperture and the flight deck door had been blown onto the flight deck where it lay across the radio and navigation console. The No 3 steward, who had been working on the cabin side of the door, rushed onto the flight deck and grasped the commander round his waist to hold on to him. The purser meanwhile removed the debris of the door and stowed it in the forward toilet. The other two cabin staff instructed the passengers to fasten their seatbelts, reassured them and took up their emergency positions.

Once the co-pilot had regained control of the aircraft he initiated a rapid descent to FL110. He re-engaged the autopilot which had become disconnected by displacement of the control column during the commander's partial egress and made a distress call on the frequency in use but he was unable to hear its acknowledgement due to the noise of rushing air on the flight deck. There was some delay in establishing two-way communications and consequently the Sector Controller was not immediately aware of the nature of the emergency. This led indirectly to the LATCC Watch Supervisor not advising the aircraft operator of the incident, as required by the Manual of Air Traffic Services (MATS) part 1. Meanwhile, the purser re-entered the flight deck and, having hooked his arm through the seat belts of the fourth crew member's jump seat, which was located behind the left-hand pilot's seat, was able to assist the No 3 steward in the restraint of the commander. The two men tried to pull the commander back within the aircraft and, although they could see his head and torso through the left Direct Vision window, the effect of the slipstream frustrated their efforts. The No 2 steward entered the flight deck and was able to relieve the No 3 steward whose arms were losing their strength as they suffered from frostbite and bruising from the windscreen frame. The No 2 steward grasped the commander's right leg, which was stuck between the cockpit coaming and the control column whilst his left leg was wedged against his seat cushion. The steward then strapped himself into the left jump seat and was able to grasp both of the commander's legs but not before he had moved a further 6 to 8 inches out of the window frame. He held him by the ankles until after the aircraft had landed.

Meanwhile, the aircraft had descended to FL100 and slowed to about 150 kts. The co-pilot had requested radar vectors to the nearest airport and had been turned towards Southampton Airport and eventually transferred to their approach frequency. Having verified that there was sufficient runway length available for a landing, the co-pilot manoeuvred the aircraft onto a visual final approach to runway 02 and completed a successful landing and stop on the runway at 0755 hours. The engines were shut down but the Auxiliary Power Unit, which the co-pilot had started up during the descent, was left running to provide electrical power to certain aircraft systems. As soon as the aircraft came to a halt, local fire services recovered the commander back into the aircraft from his position half out of the windscreen frame, where he had remained throughout the descent and landing. He was taken to hospital suffering from bone fractures in his right arm and wrist, a broken left thumb, bruising, frostbite and shock. The other crew members and passengers were medically examined but, apart from one steward who had cuts and bruising to his arm, there were no other injuries.

The pilot's windscreen was missing and one securing bolt was found in the window frame; this had retained a portion of the rubber seal and a metal bush from the windscreen. The bolt was not new and its countersunk head had pulled through the windscreen. The aircraft window frame was checked for distortion and found to be satisfactory.

Other damage to the aircraft consisted of:

The High Frequency (HF) aerial, stretching from a forward position on the top of the fuselage to a fitting close to the tailplane bullet, was missing and the fittings damaged. There was a dent on the top left side of the fuselage approximately 3 inches long about 3ft above the overwing emergency exit and a scratch on the top left side of the fuselage and minor damage to several items on the flight deck.

Engineering investigation quickly identified that the cause of the accident was a breakdown in maintenance standards at the aircraft's home base in that:

i) A safety critical task, not identified as a 'Vital Point', was undertaken by one individual who also carried total responsibility for the quality achieved and the installation was not tested until the aircraft was airborne on a passenger carrying flight.

ii) The Shift Maintenance Manager's potential to achieve quality in the windscreen fitting process was eroded by his inadequate care, poor trade practices, failure to adhere to company standards and use of unsuitable equipment, which were judged symptomatic of a longer term failure by him to observe the promulgated procedures.

iii) The airline's local management, Product Samples and Quality Audits had not detected the existence of inadequate standards employed by the Shift Maintenance

Manager because they did not monitor directly the working practices of shift Maintenance Managers.

Nevertheless, it was also evident that the air traffic control system, whilst not the cause of the accident, had not given appropriate assistance to the flight until it had reached the vicinity of the diversion airfield. The Air Accidents Investigation Branch therefore requested assistance from ATSI and an ATC investigator and an ATC human factors specialist joined the investigation team. Throughout the subsequent investigation a good team rapport was established and maintained which considerably eased the task.

At the time of the accident the flight was receiving an Air Traffic Area Radar Control Service from the Bristol sector of LATCC on a frequency of 132.80 MHz. The flight came under the control of Southampton Zone on frequency 131.00 MHz at 0744 hours. A transcript of ATC recorded transmissions from the onset of the emergency is reproduced at Appendix A.

The co-pilot made a 'MAYDAY' call and declared that the aircraft had suffered an emergency depressurisation and was descending to FL100 on a heading of 195°M. The controller acknowledged receipt of the 'MAYDAY' call from BA 5390 but did not attempt to establish if the aircraft could still receive his communications and, although he alerted his Chief Sector Controller (CSC), took no further action since he was waiting for further information about the emergency. He continued to operate the sector as if no emergency existed, accepting further aircraft onto the frequency with no attempt to off-load traffic or minimise radiotelephony activity. However, fortunately there was no conflicting traffic and the CSC had advised the neighbouring sectors of the emergency descent and told the LATCC watch supervisor and the RAF Distress and Diversion Cell about the emergency call. Nevertheless, the LATCC controller was never aware of the true state of affairs throughout the emergency sequence and, as a consequence, the initiation of the airline's Emergency Procedure Information Centre plan was delayed.

Just prior to the handover to Southampton, BA 5390 was descended to an altitude of 4000ft in error rather than FL40 as had been co-ordinated, despite the Bristol Sector Controller not being aware of the airfield's QNH. This difficulty was resolved when the flight was transferred to the Southampton Zone Controller who had been alerted to the possibility

of the aircraft landing there and had taken alerting action following a telephone call from LATCC.
The co-pilot did not select the special purpose Secondary Surveillance Radar transponder code (7700) to indicate an emergency condition but retained the code that had been already allocated to the flight. This accorded with the United Kingdom Aeronautical Information Publication RAC 7-4 which stated: "....if the aircraft is already transmitting a code and receiving an air traffic service that code will normally be retained".

ATC handling of emergencies

Guidance to controllers on the handling of emergency traffic is contained in the MATS Part 1 paragraph 5.1.7 which states:-
'Emergency aircraft - Selection of controlling agency
on receipt of information which indicates that an aircraft is in an emergency, the controller must decide whether or not to transfer the aircraft to another agency. The choice of agency will depend upon the circumstances and no hard and fast rules apply. The following guidance material will help controllers to make this decision:
Retaining Control

If the controller can offer immediate assistance the aircraft should normally be retained on the frequency. If necessary impose a radio silence on other aircraft or transfer them to another frequency.
Alternatively it may be more expedient to transfer the emergency aircraft to a discrete frequency, particularly if a radio silence would endanger other traffic.
The aircraft will have to be retained on the original frequency if it is unreasonable to ask the pilot, or if he is not prepared, to change frequency.
The controller may be able to relay instructions and information from other units to the pilot.
Transferring Control

If a controller considers that another unit may be able to give more assistance than he can himself, and in the circumstances it is reasonable to ask the pilot to change frequency, he shall either;

a) Consult the Air Traffic Control Centre Supervisor and transfer the aircraft according to his instructions, or

b) Alert the nearest suitable unit and transfer the aircraft to a common frequency, giving assistance to that unit as required.

Before transferring aircraft, controllers should obtain sufficient information from the pilot to be convinced that the aircraft will receive more assistance from another unit. If a change of frequency is desirable, the pilot must be instructed to revert immediately if there is no reply on the new frequency. Controllers should then listen out on the original frequency until the aircraft is known to be in two way communication.'

ATC training

At the time of the incident an ATC service in the United Kingdom could be provided only by a person who held an Air Traffic Controller's licence with the appropriate rating made valid at the ATC unit at which the service was to be provided. The Air Navigation Order authorised the grant of licences to persons who demonstrated their knowledge, experience, competence, skill and physical and mental fitness to the satisfaction of the CAA. The CAA published details of the evidence which had to be furnished, the examinations which had to be passed and other requirements which needed to be met before licences, rating, validations and endorsements were issued.

An applicant for a licence was required to demonstrate his or her knowledge and skill by passing examinations at two levels:-

a) Rating. The ability to provide a particular type of ATC service (eg aerodrome control, area control or area radar control).

b) Validity of a Rating. The ability to provide an ATC service at a particular place. This includes the ability to operate equipment (eg radar) when it is used to provide the service.

The Bristol Sector Controller had completed an approved course and examination for the issue of an Area Procedural and Area Radar rating at the National Air Traffic Services (NATS) College of Air Traffic Control (CATC) in May 1985 and was then posted to LATCC for validity training This was successfully completed and led to the rating being validated on the Bristol Sector position.

Prior to the mid 1980s the Area Radar rating examination had included an emergency exercise. Both the CATC and the ATC Licensing Branch informally agreed that the inclusion of an aircraft emergency during the examination placed undue emphasis on the emergency and worked against assessing the examinee's ability to handle routine traffic situations. In order to overcome this problem, an agreement was reached between the College and ATC Licensing Branch that the emergency would be removed from the examination but that appropriate training for such events would continue to be given. The Bristol Sector Controller on duty at the time of the emergency had undertaken his course in 1985 but the precise content of his course could not be established as the records of courses conducted at that time were not available.

This situation is believed to have continued until 1988 when the ATC Licensing Branch was removed from NATS and placed with the CAA Safety Regulation Group, eventually becoming part of the Air Traffic Services Standards Department (ATSSD). Due in part to that change, the CATC, which remained within NATS, was required to submit to annual inspections by the ATSSD so that approved courses might continue. In contrast to other ATC courses which had a published syllabus (CAP 390 - ATC Training Manual) no such publication was made for Area Procedural/Area Radar Courses As the CATC was the only establishment to provide such courses, individual syllabuses were agreed between ATSSD and the College. No mention of practical emergency training was given in this syllabus for area radar nor in the course approval which was given after the ATSSD inspection in 1989. The syllabus did require certain parts of MATS Part 1 relating to emergency training to be covered but instructors took a wider view and also tended to discuss the handling of emergency situations during theoretical lessons. The instructors, however, found it more difficult to incorporate emergency situations into routine practical exercises as they found it was likely to disrupt the learning process. Such training tended to be injected at a relatively early stage of the course with little opportunity for later consolidation. Therefore, the course manager was allowed to omit certain emergency situations. As a consequence, training in practical emergencies could be reduced to such an extent that it was non-effective As the syllabus did not require practical emergency instruction, the CATC management did not inform ATSSD where such training was not given. ATSSD was not aware that such decisions had been taken and believed the situation remained as per the agreement following the removal of emergencies from the examination. Once a student left the College there appeared to be no requirement to undergo any emergency training or periodic appraisal on emergency procedures in order to maintain an Area/Area Radar validated rating.

As stated earlier, this incident was not the first event to indicate that some controllers in the UK showed deficiencies in performance when it came to handling abnormal or emergency situations. Data from previous investigations revealed a worrying trend culminating in the incident in question. All too often there had been a tendency by the ATC units concerned to regard these incidents as simply "one-offs"; the result of inadequate individual performance rather than as indicative of a major defect in the system as a whole. Although this incident was not essentially an ATC event, having its roots in poor maintenance practices, the potential gravity of the incident involving the BAC One Eleven forced a re-think and led to a close investigation of the system as a whole, including the regulatory aspects.

From the Human Factors perspective, the controller's performance has many of the hallmarks of an individual performing under stress. The controller heard the MAYDAY call and would have been aware, from the outset, that he had a potentially grave situation on his hands but he subsequently went on to display a reluctance to take effective control of the situation. His actions suggest that he wished to rid himself of responsibility for this aircraft. Throughout the duration of the incident sequence he gave priority to other aircraft; provided minimal responses to the BAC One Eleven; talked over its transmissions; displayed a lack of authority and assertiveness, made no attempt to gain additional information; lacked a positive plan of action; attempted to transfer the aircraft to another agency as soon as possible; made only minimal communication with his colleagues and overall displayed a lack of ability and a reluctance to deal with the situation with which he was faced.

When interviewed, the controller described himself as feeling two basic emotions at the time of the incident. The first was a feeling of being unable to cope; while the second was a wish to try, as he put it, to "normalise" things. He explained that he felt able to deal with the problem-free aircraft under his control but totally inadequate to the task of handling the MAYDAY. His priorities became distorted and he began to solve the problems he could rather than those he should. The (sometimes unnecessary) service provided to, and level of communication with, the other aircraft on the frequency was an illustration of his attempt to embrace the normal while trying to avoid facing up to the abnormal and potentially grave situation posed by the BAC One Eleven.

It should be emphasised at the outset that this was not an incompetent controller. Among the occurrences on the database there was a small but disturbing number of events in which MAYDAY and PAN calls have not been "heard" by controllers or heard but not interpreted as an emergency call. In these cases, the controllers variously stated that they had not heard these calls at all, heard "something" but did not register its significance or heard "something" which worried them but which was accompanied by an overwhelming feeling of disbelief - a feeling that "it can't be happening to me!". Unless these controllers were lying, and we do not believe this to be the case, these incidents can be seen as involving a more extreme form of the behaviour displayed by the controller in this accident.

The controller involved was a civilian in his early thirties who had been qualified for four years at the London Centre He had no recorded ATC problems, no domestic problems, had not been ill or absent from work for any length of time and was not taking any medication. He had successfully completed his training at the College of Air Traffic Control and had passed, without difficulty, his regular competency checks. In other words, he represented the "backbone" of the ATC community at one of the busiest ATC centres in the world. He was, in effect, the "average" controller.

The recommendation in the report on the incident, that training in emergency handling should be mandatory for all controllers, was not universally welcomed. Disappointingly, a number of arguments were put up to justify the *status quo*, sometimes by those who should have known better.

It was argued, for example, that, since Air Traffic Control is such a "hands-on" activity, a controller's skill can be adequately maintained by constant daily practice - just by doing the day job. While this may be the case for much of the task, it is certainly not true of the more unusual or unanticipated events such as emergencies, which, by virtue of their rarity, do not provide sufficient practice for controllers to maintain the necessary coping skills and strategies. It was also argued by some that, since all emergencies are essentially different, they cannot be programmed into the training. The logical conclusion to this train of thought is that if we can't train for all - we should train for none.

Realistically, of course, it certainly would be totally impracticable to train for all possible abnormal or emergency events, particularly in a system as complex and dynamic as aviation. Even if all possible situations could be imagined (and this incident suggests that this is highly unlikely), the time needed to cover the training and the costs involved would be prohibitive. However, this is not the aim of emergency training. The aim should be the development of generalisable skills which can be adapted to meet a wide range of problems. While no two emergencies will be identical, there will be a number of basic steps which have to be taken in dealing with all of them. In ATC terms this would include ensuring that there are no other conflicting aircraft, ascertaining the full extent of the problem, informing the emergency services etc. Such training cannot guarantee error free performance but it can help to ensure that these common elements of emergency handling are as well rehearsed and as near "automatic" as possible so that spare capacity is released for coping with the unanticipated or unique aspects of each case. In this way it should be possible to build a repertoire of responses, skills and attitudes to increase confidence, possibly reduce stress reactions and render the controller more capable of dealing with the unexpected. It was such a repertoire that the system signally failed to provide for this controller. The aim of training in the handling of emergencies is not to engender the feeling that every session contains an emergency waiting to happen. Any controller who adopted this attitude would, no doubt, be far too stressed to do the job with the obvious consequences for safety, not to mention the mental health of the controller concerned. What needs to be developed is the ability to make realistic appraisals of situations ie to know when to be worried but with the confidence to handle whatever fate, or inadequate maintenance, can bring. The piloting community have adopted such training over many years, unfortunately, the concept had not been widely transferred to the air traffic control sphere.

The provision of training in the handling of emergencies is a costly business running to many millions of pounds. It also requires time and expertise. The regulatory decision taken by the UK Safety Regulation Group to mandate such training for all UK controllers was, therefore, not taken lightly. However, as a result of the recommendation made in the AAIB report on the occurrence involving the BAC One Eleven, that is precisely what was done. From 1994 it became mandatory for each UK ATC unit to have in place approved training in emergency handling. Guidelines for such training were developed by SRG under the, rather unfortunate, acronym ECT (Emergency Continuation Training). No wires were used, however. Since its inception, this scheme has been closely monitored and in 1999 a re-vamped set of guidelines was published, again by SRG, to broaden the scope of the training to include, among other areas, greater focus on unusual events rather than just emergencies and a much greater emphasis on the team related aspects. This change of emphasis was reflected in the rather more acceptable (and less worrying) acronym TRUCE (TRaining for Unusual Circumstances and Emergencies).

As a matter of routine, all controllers interviewed by ATSI in connection with incidents or accidents are questioned on their experience of TRUCE - its content, value to the operational task etc. The responses have generally been very favourable and TRUCE is now seen as a necessary and valuable part of the development and maintenance of operational skills by controllers and management alike.

Consideration of any aspect of training, not least one as costly and time consuming as TRUCE, begs the obvious question of whether and to what extent such training transfers to the real world. In other words - "does it pay off?". It is often difficult to provide concrete evidence for the value of such initiatives in improving safety. However, such evidence is sometimes available. In 1995 the commander of a British Midland B737 en route from East Midlands Airport in the UK to Lanzarote in the Canary Islands informed Air Traffic Control that he wished to return to the airport since indications showed dangerously low oil pressure in both engines. (It subsequently transpired that during borescope inspections on the aircraft's engines the previous night the high pressure (HP) rotor drive covers, one on each engine, had not been refitted, resulting in the loss of almost all of the oil from both engines during flight) The situation deteriorated and a MAYDAY was declared at the controller's instigation The controller informed the crew that Luton airport was their closest diversion; assisted the crew by minimising transmissions but ensuring that he passed all relevant information and arranged direct routeing and descent towards the chosen airport. This incident is worth comparing with the BAC One Eleven event. In both, the major causal factor was a deficiency in the maintenance process leading to a potentially grave situation However, the behaviour of the controllers involved could not have been more different. In this incident the controller on duty handled the occurrence in a manner which could best be described as "text book", taking all the necessary steps to ensure a safe outcome. During the course of the subsequent investigation, the controller, a young trainee being monitored by an equally youthful mentor, was congratulated on his performance. In response, he pointed out that he had known exactly what to do since he had received training in handling emergencies just the day before the incident occurred. He was also at pains to point out a number of shortcomings he had noted in his own performance and felt he could have done better. Despite the controller's modesty, it was in no small part due to his efforts and the training he had received that the full complement of passengers and crew were able to walk unharmed from the aircraft.

One of the advantages of having a dedicated, multi-disciplinary ATC incident investigation team to cover the whole of the UK is that they find themselves in the position of being able to monitor the effects of such interventions as mandatory emergency training. Since the introduction of this training there have been notable improvements, not only in dealing with the big, potentially disastrous events, but also in the handling of smaller occurrences to prevent their developing into something more serious. Improvements in other aspects of the task have also been evident, most notably in the area of phraseology.

On a wider front, a number of States have also seen the benefits of the adoption of regular emergency training for air traffic controllers with some being kind enough to recognise the initiatives taken by the UK as a trigger for their own programmes. In addition, on a Europe wide basis, the Eurocontrol European Manual of Personnel Licensing - Air Traffic Controllers now contains a requirement that ATC units must include emergency training in their training procedures.

Any incident or accident from which no lessons are learned is a tragic, wasted event. The BAC One Eleven accident is proof that lessons can be learned effectively and improvements in safety made, if there is the will to do so. While this might bring a certain satisfaction, there are no grounds for complacency. Investigation of the accident revealed severe flaws in the ATC system, not least in the regulatory aspects of that system. Had the investigation not looked at the system failures and focused simply on errors committed by individuals, a major opportunity for improvement would have been lost and the safety of aviation, in the UK at least, would have suffered as a result.

附錄十

海灣航空公司 GF072 班機失事調查

FLIGHT GF072 ACCIDENT

AIRBUS A320

23 AUG. 2000

BAHRAIN

By
Salah Mudara,

Manager Flight Safety - Gulf Air

FLIGHT GF-072 ACCIDENT

AIRBUS A320, REG. A4O-EK - 23 AUG. 2000 BAHRAIN

Salah Mudara - ISASI MO4371
Manager Flight Safety - Gulf Air

Salah Mudara has been with Gulf Air for 25 years at the company headquarters in Bahrain.
Served as an Engineer in various positions in the Technical Division before being appointed Manager Flight Safety in 1995. Graduated from AST Aeronautical Engineering School in Scotland Has an International Aviation Safety Certificate from SCSI. Member of IATA SAC, Arab Air Carrier Organization Safety Committee, ISASI and FSF. Member of Airbus & GAIN WG "A" "Flight Safety Manager's Handbook".

Introduction

On 23rd August 2000, about 1930 Bahrain local time, (16 30 GMT) Gulf Air flight GF-072, an airbus A320-212, Sultanate of Oman registered aircraft A40-EK, crashed at sea about 3 miles north-east of Bahrain International Airport.

Since the Accident Investigation Final Report had not yet been released at the time of preparation of this paper, the following is a summary of information provided by the Civil Aviation Affairs of Bahrain in the Accident Investigation Factual Report of GF072. However, the Final Report is due for release in August 2001.

Factual Information

GF-072 departed Cairo International Airport, Egypt (CAI), with 2 pilots, 6 cabin crew, and 135 passengers on board, for Bahrain International Airport (BAH), Muharraq, State of Bahrain. GF-072 was operating as a regularly scheduled international passenger service flight and was on an instrument flight rules (IFR) flight plan. The airplane had been cleared to land on Runway 12 at BAH, but crashed at sea about 3 miles north-east of the airport soon after initiating a go-around, following the second landing attempt. The airplane was destroyed by impact forces, and all 143 persons on board were killed. Night, visual meteorological conditions existed at the time of the accident.

The flight crew arrived at the departure gate at CAI about 25 minutes before the scheduled departure time of 1600 (Cairo local time) (Cairo and Bahrain are in the same time zone during the summer) on 23rd August 2000 and the flight was airborne at 1652. According to the cockpit voice recorder (CVR), the captain was performing the pilot-flying (PF) duties, and the first officer was performing the pilot-not-flying (PNF) duties. About 1921:48, as GF-072 was descending through approximately 14,000 feet above mean sea level (AMSL) and about 30 nautical miles (NM) north-west of Bahrain Airport, Dammam Approach gave the following instruction to GF-072:

Gulf Air zero seven two, uh, self navigation for runway one two is approved. Three point five (3,500 feet) as well approved and Bahrain Approach one two seven eight five (127.85 MHz) approved.

During the readback several seconds later, the captain asked, "***Gulf Air zero seven two, confirm we can go for runway one two?***" Dammam Approach responded, "***Affirmative. Three approves (approvals) you have. Direct for one two (Runway 12). Three point five (3,500 feet) approved. One two seven eight five (127.85 MHz) approved.***"

The CVR then recorded the captain instructing the first officer to contact Bahrain Approach. After the first officer made contact, Bahrain Approach stated, ***"......cleared (for) self position and, uh, as you're cleared by Dhahran. Confirm three thousand five hundred (3,500) feet."*** The CVR then recorded the captain telling the first officer, ***"tell them we are cleared to seven thousand (7,000 feet)."*** The first officer complied and Bahrain Approach responded again to flight GF-072 to continue descent to 3,500 feet.

After the flight crew began executing the approach checklist, Bahrain Approach instructed GF-072 at 1923:21 to continue descent to 1,500 feet and report when established on the VOR/DME for Runway 12. About 1923:36, the CVR recorded the first officer asking, ***"V bugs?"*** and the captain responded, ***"V bugs, one three six (136 knots), two zero six (206 knots), set."*** About 1924:38, the CVR recorded the captain saying to the first officer, ***Now you see you have to be ready, for all this, okay? If (it) change on you all of a sudden, you don't say I'll go. You have to know DME. If you can make it or not. Okay?*** This was followed by another comment by the captain, ***Now, I've just changed all the flight plan, RAD NAV (Radio Navigation), everything for you, before you even blink. Yeah?***

About 1925:15, with the airplane about 9 nm from Runway 12, 1873 feet above ground level (AGL), and an airspeed (computed airspeed recorded by the FDR) of 313 knots, the captain stated, ***"final descent is seven DME."*** *(Stated distances from GF-072 to Runway 12 are to the runway's displaced threshold. The runway's displaced threshold is 2.1 nm from VOR/DME facility. Hence, the DME distance is different than the distance to Runway 12).* At 1925:37, with the airplane about 7.7 nm from Runway 12, 1715 feet AGL, and an airspeed of 272 knots, the captain instructed the first officer to ***"call established"***. About 1925:45, about 7 nm from the runway, Bahrain Approach cleared GF-072 for the VOR/DME approach to Runway 12 and instructed the flight to contact Bahrain Tower. About 1926:00, the CVR recorded the captain saying, ***"final green"***, and at 1926:04 the first officer contacted Bahrain Tower and stated that GF-072 was ***"eight DME, established."*** Tower controller then cleared GF-072 to land and reported wind from 090 degrees at eight knots. The first officer acknowledged the transmission. About 1926:13, with the airplane about 5.2 nm from the runway, 1678 feet AGL, and an airspeed of 224 knots, the captain called for ***"flaps one."*** Seconds later, the captain called for ***"gear down"***, and FDR data subsequently showed the landing gear moving to the gear-down position.

About 1926:37, the CVR recorded the captain stating, **"Okay, visual with airfield."** Seconds later, FDR data showed the autopilot and flight director being disengaged. About 1926:49 and about 2.9 nm from the runway, the airplane descended through 1,000 feet AGL. About 1926:51, with the airplane about 2.8 nm from the runway, 976 feet AGL, and 207 knots, the captain stated, ***"Have to be established by five hundred feet."*** Flaps ***"two"*** were then selected. As the flight continued on its approach for Runway 12, the captain stated about 1927:06 and again about 1927:13, ***"....we're not going to make it."***

About 1927:23, the captain instructed the first officer to ***"Tell him to do a three sixty (360 degree) left (orbit)."*** The first officer complied and the request was approved by Bahrain Tower. The left turn was initiated about 0.9 nm from the runway, 584 feet AGL, and an airspeed of 177 knots. During the airplane's left turn, FDR data showed the flap configuration going from flaps ***"two"*** to flaps ***"three"*** and then to flaps full. About 1928:17, the captain called for landing checklist. At 1928:28, with the airplane approximately half-way through the left turn, the first officer stated, ***"landing checklist completed."*** After about three-fourths of the 360 o turn, the airplane rolled out to wings level.

FDR data showed that the airplane's altitude during the left turn ranged from 965 feet to 332 feet AGL, and that the airplane's bank angle reached a maximum of about 36 degrees. About 1928:57, after being cleared again by Bahrain Tower to land on Runway 12, the captain stated, ***"...we overshot it."*** FDR data then showed the airplane beginning to turn left again, followed by changes consistent with an increase in engine thrust. About 1929:07, the captain stated, ***"tell him going around"*** and FDR data indicated an increase to maximum TOGA engine thrust. Bahrain Tower responded with, ***"I can see that. Zero seven two sir uh....would you like radar vectors....for final again?"*** The first officer accepted, and Bahrain Tower instructed the crew to, ***"fly heading three zero zero (300 degrees), climb (to) two thousand five hundred (2,500) feet."*** *(FDR data indicate that the autothrust remained active throughout the approach, until TOGA was selected).*

The first officer acknowledged the transmission. During this time, the flaps were moved to position ***"three"*** and the gear was selected up. FDR data showed that the gear remained retracted until the end of the recording. About 1929:41, with the airplane at 1054 feet AGL, at an airspeed of 191 knots, and having just crossed over the runway, the CVR recorded the beginning of a 14-second interval of the aural Master Warning (consistent with a flap-overspeed condition), followed by the statement from the first officer, ***"speed, overspeed limit..."*** Approximately two seconds after the beginning of the Master Warning, FDR data indicated a forward movement of the captain's side stick. The captain's side stick was held forward of the neutral position for approximately 11 seconds, with a maximum forward deflection of about 9.7 degrees reached (Maximum fore and aft sidestick deflection is 16 degrees from the neutral position). During this time, the airplane's pitch attitude decreased from about 5 degrees nose-up to about 15.5 degrees nose-down, the recorded vertical acceleration decreased from about +1.0 "G" to about +0.5 G's, and the airspeed increased from about 193 knots to about 234 knots.

About 1929:51, with the airplane descending through 1004 feet AGL at an airspeed of 221 knots, the CVR recorded a single aural warning of *"sink rate"* from the Ground Proximity Warning System (GPWS), followed by the repetitive GPWS aural warning *"whoop whoop, pull up"*, which continued until the end of the recording. *(Gulf Air procedures for response to a GPWS warning of "WHOOP WHOOP PULL UP" stipulate that full back stick is to be employed and maintained, and that during night conditions, the response should be immediate).*

About 1929:52, the captain requested, ***"flaps up".*** About 1929:54, the CVR indicated that the Master Warning ceased for about 1 second, but then began again and lasted about 3 seconds. Approximately 2 seconds after the GPWS warnings began, FDR data indicated movement of the captain's side stick aft of the neutral position, with a maximum aft deflection of approximately 11.7 degrees reached. However, the FDR data showed that this nose-up command was not maintained and that subsequent movements never exceeded 50% of full-aft availability. FDR data indicated no movement from the first officer's side stick throughout the approach and accident sequence.

About 1929:59, the captain requests, ***"flaps all the way"*** and the first officer responded, ***"zero".*** This was the last comment from the crew recorded on the CVR, which stopped recording at 1930:02. The FDR data showed continuous movement of the flap position toward the zero position after the captain's ***"flaps up"*** command. The last flap position recorded on the FDR was about 2 degrees of extension.

The last recorded pitch attitude was about 6 degrees nose-down and last recorded airspeed was about 282 knots. FDR data indicated that TOGA selection and corresponding maximum engine thrust remained until the end of the recording.

FDR data indicated that during the go-around after selection of TOGA thrust, GF-072 was initially at about a 9 degree nose-up pitch attitude. However, the pitch attitude gradually decreased to about 5 degrees nose-up over the next 25 seconds, where it remained until the captain's forward sidestick commands resulted in nose-down pitch changes.

Attached Figure shows an overhead view of the GF-072 trajectory, with selected FDR information, CVR comments and sounds, and air traffic control (ATC) data for the last 4 minutes of flight.

Injuries to Persons

Fatal:
Flight Crew: 2
Cabin Crew: 6
Passengers: 135:
Total: 143

The Crew

The captain, age 37, with total flying time hours of 4,416 Hrs, and total A320 PIC 86 Hrs. The Captain also had experience as First Officer on the A320 SIC 997 Hrs., B767 SIC 2,346 Hrs., L1011 SIC 800 Hrs., Flight Engineer 2,402 Hrs.

The first officer, age 25, was promoted to A320 first officer on 20 April 2000. The first officer's flight experience total Pilot Time 608 Hrs., including total Pilot in training 200 Hrs. Total A320 SIC 408 Hrs.

Flight Recorders

The flight data recorder and cockpit voice recorder were recovered on 24 August 2000. The underwater locator beacons installed on each recorder had separated during the impact sequence. The recorders were transported by a Bahrain Civil Aviation Affairs (CAA) official to the NTSB's laboratory in Washington, DC, USA for initial readouts, and thereafter to BEA's laboratory in Paris, France for further readout analysis.

Wreckage and Impact Information

The debris field was centered approximately 4 kilometers northeast and on a 030 degree radial from Bahrain International Airport. The wreckage was located in the sea in about 3 meters of water. Estimated surface temperature at sea at the time of the accident was about +3 C. The beginning of the debris field was located near 26°17'51" North/50°38'49" East. The debris field was oriented on a heading of about 030 degrees and was about 700 meters in length. The end of the debris field included portions of the cockpit and lower avionics bay. The width of the debris field varied but was approximately 800 meters at the widest point. The majority of the right and left hand structural pieces were found on their respective sides of the debris field. A broad search of the accident area and the approach to Runway 12 revealed no additional wreckage.

The majority of the airplane was recovered along with all significant airplane structural and flight control surfaces and both engines. No evidence of pre-crash failure and no evidence of fire damage were observed on any of the recovered parts. All examined fracture surfaces were consistent with overload failure. Damage to circuit breaker panels precluded proper documentation of pre-impact circuit breaker positions or conditions. The fuselage had fragmented into numerous sections. The wings were sheared from the center box structure near the same location on both sides. Both engines had separated from the pylons and were heavily fragmented. A large section of the empennage was found in one piece.

Portions of the nose gear and both main landing gear (MLG) assemblies had separated. The right hand MLG retraction actuator was found in the extended position, which corresponds to a "gear retracted" position; the retraction actuator for the left hand

MLG was not located. Most of the horizontal stabilizer was recovered separate from the empennage and was substantially fragmented. The horizontal stabilizer actuator screw was broken with the lowest part remaining connected to the ballnut. The length of the screw from the ballnut corresponded to an estimated 2 degrees nose down attitude. The left side pitch trim control wheel was recovered in good condition; the right side was found fractured and jammed. The pitch trim index showed approximately 1.5 degrees nose down.

Slat position measurements on all the slats showed a 12 degree slat extension. Flap position measurements indicated that the flaps were within 2 degrees of the flap fully retracted position. The flaps/slats control box was recovered with the command handle jammed in position "2" but pulled out of the lock gate. The spoilers control box was recovered in good external condition with the handle found in the retract position and the auto ground spoilers not armed. Both engines sustained damage consistent with impact and water immersion. Most of the fan blades were found broken just above the root or between the root and mid-span. The remaining portions of the fan blades were bent opposite to the direction of rotation. The engines were found split open in various locations. Examination of the rotating parts within each engine revealed evidence of rotational smearing, rubbing, and blade fractures that were consistent with the engines producing power at the time of impact.

Neither engine exhibited any evidence of uncontained failures, case ruptures, or in-flight fires. All of the thrust reverser actuators that were found indicated that the thrust reversers on both engines were in the stowed position.

Tests and Research

Recovery Study

Although data were obtained during simulation and flight test activities, an additional study of GF-072's final trajectory was performed to determine the effect of certain variables on altitude loss during GPWS recovery. The variables that were examined were 1) the amount of the pilot's pitch-up command; 2) the time between GPWS warning and the pilot's reaction; and 3) the length of time of the pitch command input. To determine the altitude lost during the recovery, the following scenarios were evaluated assuming the same conditions that existed with GF-072 when the GPWS warning began (altitude, pitch attitude, airspeed, descent rate, etc.). Calculations for the study indicated that the first GPWS alert were consistent with the altitude at which GPWS alerts started on the GF-072 FDR.

GF-072 Simulation

A series of simulations were organised on 26th and 27th September, 2000 at Airbus Industrie's facilities in Toulouse. An A320 fixed base engineering simulator was used in an attempt to simulate the approach, orbit, and go-around of GF-072 at BAH. The investigation committee was assisted by an Airbus chief test pilot and an Airbus flight test engineer. The simulator sessions also allowed investigative team members to fly the approach to Runway 12 and observe cockpit warnings during the overspeed and GPWS warnings. Several scenarios were flown. During one of the simulator sessions, the 360° turn and go-around maneuvers were performed to approximate the flight path and sequence and timing of events recorded on the FDR recovered from A40-EK. However, in these scenarios, the pilots were instructed to recover with full aft stick movement at the onset of the ground proximity warning system (GPWS) "whoop, whoop, pull up" alert. In this scenario, the simulator recovered with about 300 feet of altitude loss.

In the following scenario, a half-back stick command was applied instead of a full back stick command. The delay between the GPWS warning and the stick command was approximately 4 seconds. In this scenario, the simulator recovered with about 650 feet of altitude loss. In another scenario a recovery was performed by the co-pilot after he verified that the captain took no action to recover from the GPWS "whoop, whoop, pull up" alert. The co-pilot depressed the priority button on his sidestick, announced his control override, and applied full aft side stick input. In this scenario, the simulator recovered with about 400 feet of altitude loss. In another scenario the 360 degree turn was performed as described above. However, upon selection of TOGA power, the pilots were instructed to make no further control inputs. In this scenario, the simulator trimmed nose down in order to counter the nose up effect due to the thrust increase and to maintain +1.0G, which is the target when the stick is in the neutral position in normal law. The pitch remained positive and the aircraft climbed slowly. This is because the pitch was positive at the beginning of the maneuver. In normal law, +1.0G is maintained even in a pitch up attitude if the speed (and thus the vertical speed) is constant.

In the final scenario demonstrated, the 360 degree turn was initiated to match the flight path and sequence and timing of events recorded on the FDR recovered from A40-EK. However, instead of rolling the wings to level upon reaching a heading of about 211 degrees magnetic, the turn was continued at a moderate bank angle at the pilots discretion to align with Runway 12 and the approach and landing were continued. In these demonstrations the pilots were able to successfully land on runway 12 from the 360 degree turn. However, the pilot's noted that the approach was not stabilised and a short amount of time was available to successfully complete the final approach and landing. While in the simulator, the group examined the reach distance from the left seat to the emergency cancel pushbutton, which is located on the ECAM control panel on the central pedestal. The group concurred that the reach distance to the emergency cancel pushbutton was not very far and reaching for it from the left seat was not likely to cause an inadvertent forward side stick deflection.

Flight Tests

On September 27, 2000 a flight demonstration was conducted to observe various conditions similar to the flight profile flown by GF-072 on August 23, 2000. The flight demonstration was conducted during daytime in visual meteorological conditions. The flight test was conducted in an Airbus A320 test aircraft. The Airbus chief test pilot was the pilot-in-command of the test flight, which was coordinated by an Airbus test flight engineer. Other participants and observers were members from the Technical Investigation Committee including CAA Bahrain, NTSB, BEA representatives as well as Gulf Air, Airbus and FAA technical advisors. The co-pilot was alternatively the chairman of the Technical Investigation Committee and a Gulf Air A320 chief pilot.

Starting from level flight in an clean configuration, manoeuvres were performed to achieve a +0.5G nose down attitude which was held for about 10 seconds. All occupants on the test airplane noted that the +0.5G condition was highly noticeable. A second test was performed to assess the sensation during the acceleration in climb with a constant 5 degrees nose-up pitch attitude at TOGA power. Non-flying occupants were instructed to close their eyes during the manoeuvre to simulate the absence of visual references. None of the occupants on the airplane reported to have perceived a significant increase of pitch. Additional tests were performed to simulate the 360 degree orbit of the accident flight, yet continuing to turn at the end of the orbit (instead of rolling out). Several scenarios were flown, with a similar flaps sequence as in GF-072 or with full flaps being selected at the pilot's discretion. The pilots were able to align the airplane with the runway and perform low approaches down to 50 feet where a go-around was performed.

Overwater Light Visibility Study

To determine the surface lighting and overwater visibility conditions that might have existed at the time of the accident, investigation group members observed the area of the crash site several hours after sunset on 2 September 2000. The area was viewed from three different locations: the control tower located on the airport, a point along the shoreline Southwest of the approach end of Runway 12, and a jetty Southwest of the crash site. As on the night of the accident, there was no visible moon and ceiling and visibility were CAVOK at the times of the observations. On the day of the study, the observers noted that no lights were visible along the horizon over the water looking to the north or Northeast toward the crash site. The observers noted that a few scattered stars were visible in haze from the shoreline and jetty locations. No lights from ships, boats, or buoys were observed on the water from the locations.

Flap Lever Examination

FDR data and flap actuator measurements indicated a flap position of approximately 2 degrees at impact. However, examination of the flap lever after recovery of the wreckage revealed that the flap lever was in position "2" (which would be consistent with a flap position of 15 degrees). The flap lever and the power control unit, including both flap position pick-off units (which provides the FDR flap position data), were sent to the vendor for examination under control of the CAA. Electrical and mechanical tests of the position pick-off units revealed a flap position between one and two degrees.

Crew Pairing

Flight crew who have recently converted to the aircraft type, or have recently been upgraded to Commander, will be restricted to which crew members they may operate with and their roster will be marked with a blue line. The blue line period extended from the initial line check until a minimum of 40 sectors have been completed in the respective crew category, on Gulf Air operations. This was changed to "20 Sectors (for newly promoted Commanders) and 10 Sectors (for pilots transferring from another fleet)" from 15 August 1999. This was in accordance with the minimum requirements specified in the regulations. (The crew of the accident aircraft were not effected with the change)

ICAO Special Evaluation

In response to a request by the DGCAM, a consultant from the International Civil Aviation Organisation (ICAO) conducted a special evaluation to review the level of Gulf Air's compliance with Civil Aviation Regulations. The special evaluation was done from 17 October through 21 October 1998. During this period, DGCAM personnel and Gulf Air Flight Operations managers were interviewed and an A320 cockpit enroute check was conducted. Numerous correspondence documents as well as circumstances of recent incidents regarding non-compliance of regulatory requirements were reviewed. The following are two of the conclusions from the above review:

- delayed or non-compliance with regulatory requirements,
- Gulf Air's opposition to CAR 121.

Based on this review the ICAO letter to DGCAM dated 25 October 1998 stated that, except for isolated incidents, most infractions could be traced to inadequate supervisory oversight rather than deliberate disregard for the regulations. However, the regulatory compliance level by Gulf Air Flight Operations was assessed as satisfactory.

Gulf Air Post-accident Safety Initiatives

Go-Around Procedures

In November 2000, A320 Fleet Training issued instructions to all A320 training captains regarding go-around procedures. The memo directed that all pilots are to practice two-engine go-around procedures during Simulator Continuation Training and under the following conditions:

1. Flight Directors 'ON'
2. Flight Directors 'OFF'
3. Track/FPA selected.
4. Go-around ATC clearances other than standard published go-around procedures.

(Note · Ab-initio and Upgrade Training syllabi include single and two-engine go-around training. However, the Continuation Training Syllabus included single engine go-around training, but not two-engine go-around training. This memo was issued to enhance the Continuation Training Programme).

Ab-Initio Training

Following the accident, Gulf Air suspended additional hires of ab-initio pilots until further notice. Gulf Air also suspended its Ab-Initio Simulator Training program, pending a full review, in order to assess it against industry standards and recent changes to regulatory requirements. These actions were prompted by issues arising from the GF-072 accident and by a recent DGCAM Oman Operational Directive specifying new requirements for simulator training. The intent of the directive is to increase the proportion of simulator training that is conducted with a normal crew complement (i.e., a captain in the left seat and a first officer in the right seat), rather than pilot trainees being paired with another trainee of the same level. The directive is also intended to ensure that a trainee undergoes a greater share of training in his proper seat and a more realistic operating crew environment.

Cockpit Crew Resource Management (CRM) Training

The Initial CRM Training course was already under development at the time of the GF-072 accident. Initial CRM courses for Gulf Air pilots commenced on 1 November 2000. Gulf Air's intention is to complete the Initial CRM training for all Gulf Air pilots no later than June 2001.

Command Upgrade Training

Gulf Air modified its Command Line Training program to include an additional final phase of 20 sectors (minimum) with a "normal" crew complement consisting of the upgrade trainee in the left seat, an instructor or examiner in the jump seat, and a line first officer in the right seat. This training process is intended to allow an assessment of the trainee commander's ability to operate satisfactorily with a first officer during actual line operations, with the benefit of the guidance and support available from the instructor. DGCAM Oman has approved these modifications to the training program.

Gulf Air A320 Fleet Instructions

Gulf Air has issued A320 Fleet Instructions on the following subjects:

(a) Standard Operating Procedures (SOP), A320 Fleet Instruction No. 14/2000 (Re-issue No. 1) dated 4 October 2000:

(1) Speed Control Below FL100 or 10,000ft. amsl.

(2) Stabilised Approach Criteria

(3) Visual Manoeuvring in the Vicinity of an Airport

The Fleet Instruction assures the pilots as follows:

"All pilots are further assured that no disciplinary action whatsoever will be taken against any crew that elects to carry out a go-around for safety-related reasons, including inability, for whatever reason, to stabilise an approach by the applicable minimum height."

(b) Flight Director Usage During Non-precision Approach,

A320 Fleet Instruction No. 18/2000 dated 4 February 2001.

Recurrent Training and Checking

Gulf Air is implementing enhanced training on go-around procedures for all A320 pilots during their recurrent training sessions. Gulf Air indicated that the training is intended to:

1) cover new company requirements involving speed control, stabilised approaches, and visual manoeuvring that were published in the Fleet Instructions Numbers 14/2000 and 18/2000 and

2) practice go-around procedures with both engines operating under the following circumstances:

- Flight directors on and off;
- Track/FPA (Flight Path Angle) selected;
- Go-arounds conducted in accordance with ATC clearances that differ from published procedures.

Instructor Selection and Training

Gulf Air suspended all instructor appointments on 28 September 2000 in order to allow a review and enhance the instructor selection criteria and procedures in order to comply with the DGCAM operations directive.

Pilot Selection

All first officers eligible for upgrade will be required to undergo screening tests to assess their suitability for command, including screening tests conducted by an accredited aviation psychology organisation. All ab-initio second officers and direct-entry pilots undergo screening tests conducted by an accredited aviation psychology organisation.

Modification to A320 Automatic Flight System (AFS)

Automatic Return of Flight Director (FD) Bars at Go-Around Initiation

Gulf Air is in the process of implementing an Airbus Industrie modification to the A320 Automatic Flight System. This modification will automatically re-instate the FD bars at go-around initiation. The FD bars will automatically display SRS instructions, and level wings on the track at the time of initiating "Go-Around", and will return in 'HDG/v/s' mode.

Spatial Disorientation Study

The above study is being undertaken at the US Naval Aerospace Medical Research Laboratory, Pensacola, Florida, USA. The scope of the study is expected to address the lateral and vertical acceleration and estimated perceived pitch aspects. The perceived pitch experienced by occupants of the airplane would be estimated from a computation based on the net gravitational force.

Final Report

The Factual Report, which was issued by Bahrain Civil Aviation Affairs on the Internet, is on: www.bahrainairport.com. The report can be found on the Civil Aviation page. The Final Report is due for release in August 2001.

附錄十一

新加坡航空公司 SQ006 班機失事調查心得

By

Dr. Kay Yong

Aviation Safety Council, Taiwan, ROC

Lessons Learned from SQ006 Accident Investigation

By: Kay Yong and the SQ006 Investigation Team
Managing Director and IIC of SQ006 Investigation
Aviation Safety Council, Taiwan, ROC

Background

On October 31, 2000, approximately 2317 Taiwan time (1517 UTC), a Singapore Airlines Flight 006, with Singapore registration 9V-SPK, Boeing 747-400 airplane entered an incorrect runway at Chiang-Kai-Shek (CKS) Airport, Taiwan. The airplane was destroyed by its collision with the runway construction equipment and by post impact fire. There were a total of 179 people on board with 159 passengers, 3 flight crew and 17 cabin crew. A total of 83 people died (including 4 cabin crew), and 44 people injured. Heavy rain and strong wind from typhoon "Xiang Sane" prevailed at the time of the accident.

According to ICAO Annex 13 and Taiwan Civil Aviation Law Article 84, Aviation Safety Council (ASC), an independent government organization of Taiwan responsible for civil aviation accidents and serious incidents investigations, immediately launched a team to conduct investigation of this accident. National Transportation Safety Board (NTSB) of USA, the state of manufacturer and Ministry of Communication, Information, and Transportation (MCIT) of Singapore, the state of registry and the operator joined the investigation team as the Accredited Representatives (AR). At the request of IIC, the Australia Transportation Safety Bureau (ATSB) had also sent three investigators to Taiwan as advisors and later on designated as an Accredited Representative team in accordance with paragraph 5.23 of the ICAO Annex 13. ASC also acquired a local Research Organization, Chung-Shan Institute of Science and Technology, to assist the on-scene mapping and testing of the runway edge light pigtails. Investigation commenced immediately after the accident. Basing on the nature of this accident, the investigation team was organized into nine groups: Flight Operations, Recorders, ATC, Weather, Ground Operations, Systems, Survival Factors, Aerodrome, and Human Factors. The Aerodrome and Human Factors groups were incorporated one week after the accident. A total of 78 people participated in the investigation and the organization of the investigation team is shown in Figure 1. Major highlights of the investigation process are shown in Table 1.

During the course of both the on-scene investigation, and the activities that followed, numerous lessons were learned from the operation of this international team. It is therefore the opinion of the team members that those lessons should be shared to the aviation investigation community, such that the investigation process could be improved in the future.

Logistics

1. Better coordination with the local prosecutors and the law enforcement is definitely necessary to ensure efficiency of the entire investigation process. In earlier stages of the on-scene investigation, the local prosecutor denied participation of the Accredited Representative team due to the lack of knowledge of the international law and the Taiwan Civil Aviation Law.
2. Autopsies were conducted only on eight of the eighty-three fatalities due to the lack of awareness of its importance to the survivor factors investigation. Cultural issues also need to be considered, as families of the deceased were very anxious to bury their loved ones after the tragic accident. Due to chaos by the fire and rescue effort, and the poor weather condition, drug and alcohol test of the pilots were not conducted immediately after the accident.
3. All participants of the aircraft accident investigation should be housed in one hotel or hotels in close proximity to facilitate discussions between groups. As the CKS transit hotel was fully occupied by the deceased family and the family assistance effort, such practice was not possible.
4. There should be greater inter-group coordination and sharing of information to minimize duplication of work. To this end, each group should establish its own file with findings arranged in chronological order, for sharing with other groups.
5. The investigation protocol should be established & made known to all parties.
6. The country of origin should provide individual biohazard protective gear to all investigators to walk the accident site.
7. Due to the lack of better coordination effort and the absence of the IIC at the beginning of the investigation, command post was changed three times before the commencement of the full scale on-scene investigation (the arrival of the international teams). This has created some confusion in the early stage of the on-scene activities.

Wreckage Identification / Mapping / Handling / On-Scene Data Collection

1. The wreckage identification/mapping team shall comprise one each structure,

systems, avionics and engine specialist in addition to the GPS crew. This can speed up the documentation / parts identification process.

2. With the documentation completed, the tagged parts can be moved to a storage area. This is to be determined by the group chairman and after consultation with the IIC. Other groups with interest in the wreckage must consent to this move. This is particularly important to the Survival Group, as they need to look at the fuselage wreckage to understand the survivability of the accident. They have to ensure their work is completed before the wreckage could be removed.
3. Proper assessment of how to access the recorders is very important. That includes the risk and difficulty when accessing the wreckage, especially during the poor weather condition.

Photo taking and Marking, Video

1. Starting the picture taking from the start of the impact point and then work down the path of the aircraft. By this way, a sequence could be developed.
2. The first shot of every wreckage piece shall be taken from a position behind the wreckage piece in the direction of the aircraft path. This provides a view of the wreckage in the perspective of an investigator moving down the runway. It also provides the correct orientation to the runway heading. Subsequent shots of the piece can be taken from other directions to show the best angle and details of the damage. Picture taking at the accident site was haphazard and random.
3. The reference number of many of the photos taken by Chung Shan Institute could not be seen clearly. This was due to the use of green marker on a white reflective board. The writing shall be in black thick strokes and be written on white non-reflective background. The photo reference number and the GPS position shall be indicated.
4. A short description of the damage piece shall follow. This shall include name of the part, part number and serial number information as well as the approximate dimensions. This description shall be logged against the photograph reference number. Where the part cannot be identified at the time of picture taking, the part number or serial number shall be recorded. In case these are not available, then part number of any adjacent detail part shall be recorded. This would assist in the identification of the part by checking on the next higher assembly of the detail part from the manufacturer's drawings.
5. In addition to the 35-mm prints, a digital camera shall also be used to record the wreckage pieces. A video camera is also recommended. This will have voice over feature and would provide a panoramic view of the site.
6. Should have used measuring apparatus to measure the brightness of the

questioned lights to prevent from disputing of qualitative description.

Recorders' Activities

1. As transcribing of ATC radio communications is usually a lengthy process, it should have commenced early. Additionally, a dedicated group of people well versed in ATC communications should have been formed to solely handle the ATC transcription.
2. All draft CVR transcript must be properly destroyed.
3. The CVR transcript distribution control list should be ready for internal or external distribution.
4. Spare recorders for readout should be considered after knowing the Part number of the recorder.
5. CVR audio information must be strictly controlled. CVR Non-disclosure Agreement must be signed regardless who is intended to listen to the CVR.
6. Line pilots who recognize the voice of the pilots in the CVR Group are strongly recommended.
7. CVR Group members should consist of at least one from every accredited party.
8. To avoid interruption of CVR transcribing progress, separated listening environment for other groups who need to listen to the CVR is recommended.

Team Organization, Meetings and Daily Activities

1. Conflicts are almost inevitable for an international accident investigation, especially if the nature of the accident is in human factors. The best way to resolve such conflicts is to have closer communication during the entire course of the investigation. Frequent technical review meetings are encouraged. Different opinions should be expressed in writing in the earlier stages of the investigation. This includes the factual data verification process, the analysis, and even the derivation of the recommendations.
2. An important part of the investigation process is planning carefully the activities of the team and establishing a list of priority action items. A feature of this could be a daily team meeting where the allocation of tasks is discussed and the workload distributed between the respective team members.
3. Prior to joining the team, team members should be carefully briefed as to what is expected from their participation in the group. It is important for the team members to have the same understanding of the team's objectives and the role that they will play in achieving this task. Any potential conflict with other duties should be discussed at this time and a process adopted to ensure that this would

not adversely impact on the effectiveness or efficiency of the team. The team's progress towards their objective needs to be monitored, to ensure that the investigation is kept on-track and that emerging issues can be incorporated in this process.

4. When planning activities, the team should discuss the time when a given task should be completed. This will assist in managing the workload and ensuring that the group can meet the deadline for presenting its group report. When summarizing activities, the team should bear in mind the style of report that is required from the group and milestones should be set to assist in maintaining the flow of the investigation process.
5. The group chairman should convene a meeting every morning to determine what needs to be done for the day and also to review what had been accomplished the previous day.
6. Duration of group presentations during the daily debriefs should have time limit. Each group should state findings and lessons learned during the day. This would have kept the daily debriefs reasonably concise and given each group sufficient time to meet and plan their own work for the following day.
7. Minutes of the daily debrief should have been kept and disseminated to all groups.
8. Roles of the investigation team members should have been established and defined early. This could have prevented some members from overstepping their limits.
9. Daily group meeting and progress meeting are proved very helpful in the development and control of the group activities and the direction of investigation.
10. Those of members should have enough time to work with group. More than 50% of working time absent is very bad for final verification.
11. Although most of the members are familiar with the aircraft involved, more aircraft information during the on scene phase of the investigation would definitely help the process.

Interviews

1. Careful planning and coordination is required prior to conducting interviews to ensure the group identifies the issues, which are critical to progress the investigation. The team needs to agree upon a protocol for conducting the interview and recording the information supplied.
2. Key witnesses should be interviewed by the relevant investigators as soon as possible
3. Human Factors Group should be represented in the Flight Operations, ATC and Survival groups in the interviews. This is to ensure that HF aspects are covered

in the interviews as well as to avoid additional interviews, particular on similar questions.

4. Formalities should not preclude organized interviews. From this, the following should hold:
   - All interviews organized by the state of occurrence and data subsequently collected should be submitted.
   - Interviews should not be conducted without a member of the investigation authority of the state of occurrence.

Minutes, Reports and Documentation

1. All proceedings of the meeting shall be recorded.
2. The minutes shall be kept in a file and made available to all group members as well as members from other groups.
3. Group members shall discuss the documentation process like what needs to be documented and what bearing the documentation has on the investigation.
4. All records of data, including investigation reports should follow a standard format for consistency.
5. The format of the group report should have been made available at the onset of the investigation. This would have provided the necessary guidelines for all groups to follow. The ongoing amendment of ASC SOP should consider the provision of such format.
6. Participating parties should be told very clearly that there is only one authentic group factual report for the group. Data or opinions collected other than factual information such as observations and comments will only be used for reference during analysis, not to be incorporated in the final group data collection report.

CONCLUSION:

Aviation Safety Council was established on May 25, 1998 for the purpose of improving aviation safety via systematic accident investigation. To the time of this writing, ASC has investigated a total of 13 aviation accidents and serious incidents but SQ006 is the first major accident investigation that reaches the international level. We are still a very young organization in this field that has lot to learn from the international community. It is our sincere hope that those lessons may have some values added to the investigators internationally, especially to the young organizations and to those who are considering the establishment of an independent investigation organization. We all hope that major accidents will not occur, but if indeed it happens, we would be more ready than what we had encountered during the SQ006 investigation.

Fig.1. Organization Chart

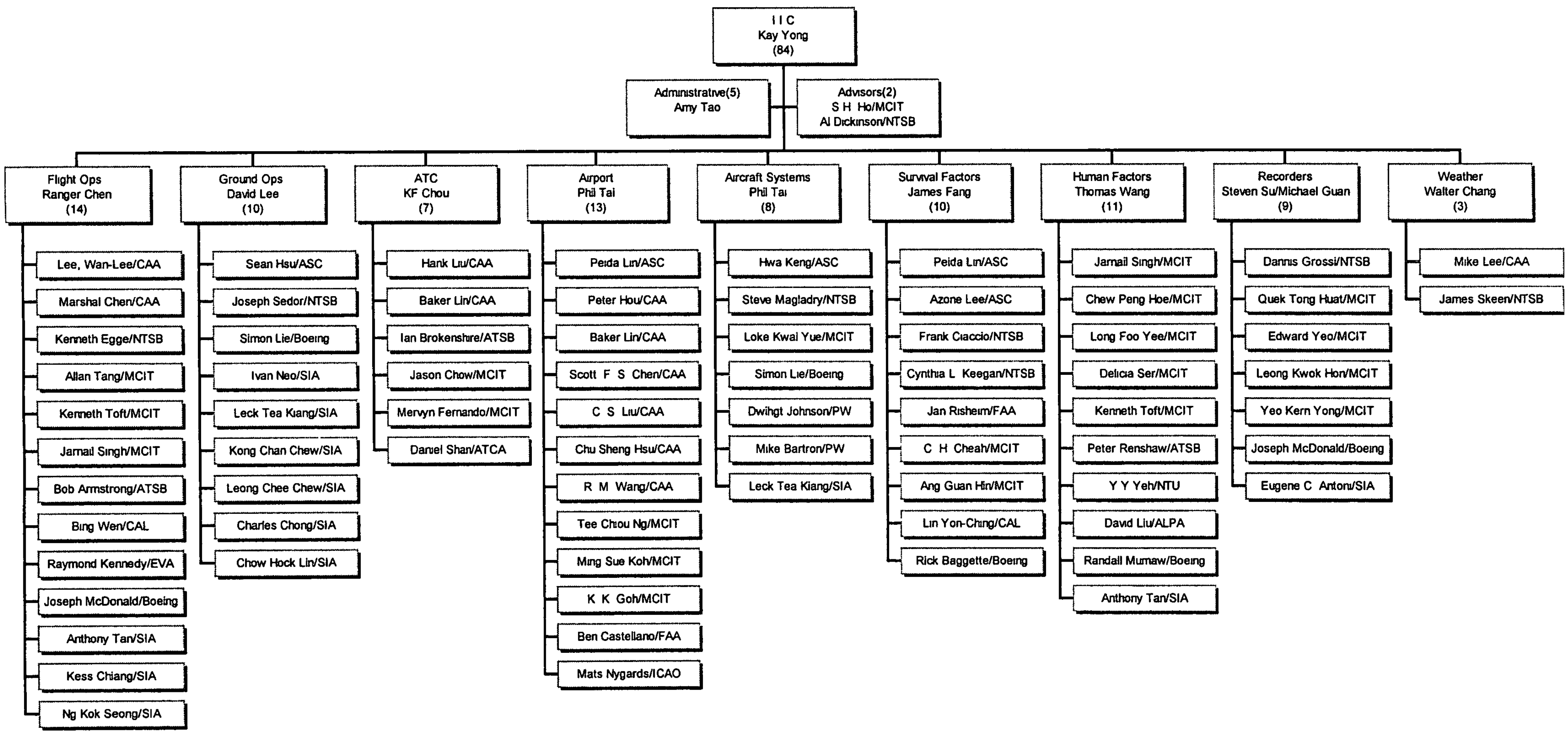


Table 1. Major Milestones

2000	10/31	Date of Accident
	11/04	Flight simulation of SQ006 completed
	11/08	Transcript of CVR completed
	11/13	On-scene investigation completed
	11/15	Wreckage removal
	11/15	On-scene report completed
	11/27	Interview SIA & CAAS
	12/04	Preliminary report published
2001	01/23	Factual data collection completed
	02/23	Factual Report posted on ASC Website
	03/01	Analysis process commenced
	07/05	Technical Review Meeting
	09/01	Draft report sent to NTSB & MCIT
	Late Nov.	Draft report submitted to ASC Board
	Early Dec	Final report published

附錄十二

近年來客艙安全調查案件

Recent NTSB Cabin Safety Investigations

By
Nora C. Marshall
National Transportation Safety Board
USA

Recent NTSB Cabin Safety Investigations

By Nora C. Marshall
National Transportation Safety Board

The United States Congress charges the National Transportation Safety Board (NTSB) with investigating every civil aviation accident in the United States. An accident is defined as an "occurrence associated with the operation of an aircraft...in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (49 CFR Part 830.2). The Safety Board is responsible for maintaining a data base on civil aviation accidents. The database contains a record for, among others, every accident involving Part 121 air carriers.

The Safety Board reviewed its accident/incident database to examine several aspects of occupant survival in aircraft accidents that occurred during air carrier operations. Each air carrier accident from 1983 (the first year of the Board's current aviation accident database) through 2000 (the last full year in the database) was reviewed. There were 568[1] accidents involving Part 121 carriers between 1983 through 2000 and 71 of the 568 accidents resulted in at least one fatality. There were 53,487 occupants involved in the 568 accidents and 96% of the occupants were survivors.

Because there may be a public perception that aviation accidents are not survivable, the Safety Board examined the proportion of accidents that were survivable. In 528 of the 568 accidents more than 80 percent of the occupants survived. Accidents that result in complete or near complete loss of life, such as TWA flight 800, account for a small percentage of all accidents. Only 34 of the 568 accidents resulted in fewer than 20 percent of the occupants surviving.

Because the occupants' survival was never threatened in the majority of the accidents, the Safety Board focused on survivability in serious accidents. For the purpose of examining this subset of all air carrier accidents, the Board defined a "serious accident" in the Safety Report as an accident that involved fire (precrash or postcrash), at least one serious injury or fatality, and either substantial aircraft damage[2] or complete destruction. The Board reviewed its accident database, accident reports, public dockets and its investigation files for information about survivability. The cause of death, obtained from autopsy reports, represented the opinion of a pathologist or coroner authorized by the State or territory to make that determination.

From 1983 through 2000, the Safety Board investigated 26 accidents involving fire, serious injury, and either substantial aircraft damage or complete destruction. There were 2,739 occupants involved in the 26 accidents. Fifty five percent of the occupants survived the accident; 26.1 percent died from impact, 12.4 died from unknown causes, 4.8 percent died from fire/smoke, and 1 percent died from other causes (drowning, mechanical asphyxia, etc.)

An important distinction between deaths from impact and deaths from fire is that impact deaths typically occur as a result of aircraft impact forces whereas fire deaths typically occur after impact.

---

[1] An accident is defined as an event that includes at least major structural damage, a serious or greater injury

[2] Substantial damage is defined in 49 CFR 830 2 as damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected equipment.

In the serious accidents, there were nearly five times more impact fatalities than fire-related fatalities. The high proportion of impact-to-fire fatalities is the result of the inclusion of a number of unsurvivable accidents in the subset.

The Board defined survivable accidents as those accidents in which the forces transmitted to occupants through their seat and restraint system cannot exceed the limits of human tolerance to abrupt accelerations, and the structure in the immediate environment must remain substantially intact to the extent that a livable volume is provided for the occupants throughout the crash. Using that definition, the Board determined that 7 of the 26 serious accident were not survivable because of impact forces. Nineteen of the 26 serious accidents involving air carriers were at least partially survivable. Seventy six percent of the occupants in these accidents survived. In 12 of the 19 serious survivable accidents, more than 80 percent of the occupants survived.

The Safety Board has also recently completed a safety study about emergency evacuation.[3] For the study, the Safety Board investigated 46 evacuations that occurred between September 1997 and June 1999 that involved 2,651 passengers. On average, an evacuation for the study cases occurred every 11 days. In the 46 study cases, 92 percent (2,614) of the 2, 846 occupants were uninjured, 6 percent (170) sustained minor injuries, and 2 percent (62) sustained serious injuries. One of the findings from the study was that air carriers do not always make reports to the Federal Aviation Administration's service difficulty reporting system, or reports are inadequate, to identify the extent of component problems or failures.

During the evacuation study, the Safety Board noted a pattern of irregularities with evacuation equipment. Problems with performance of emergency exits and evacuation slides were noted and a review of nine accidents and incidents revealed a history of malfunctioning emergency evacuation systems. The Board identified problems with slide/raft deployment and inflation, power assist systems, and questioned why the problems were not identified during the air carriers' FAA-approved maintenance programs. The Board issued 5 recommendations[4] on December 9, 1999 to the FAA about emergency evacuation system reliability.

The Board's most recent recommendation related to evacuation equipment was issued on May 16, 2001. On March 17, 2001, an Airbus A320-200 ran off the runway and onto terrain during a rejected takeoff at Detroit, Michigan. During the subsequent evacuation, three of the four floor-level emergency exits operated as designed. However, the emergency evacuation slide/raft at door 2L separated from the airplane and fell to the ground when the flight attendant opened the door.

The accident airplane was overwater equipped with slide/raft at each floor-level exit. The girt bar for overwater airplanes were designed with a telescopic girt bar. The telescopic end of the girt bar is locked in the extended position by a spring-loaded trigger. Squeezing the trigger causes the trigger locking mechanism to retract within the telescopic end of the girt bar, allowing it to slide into the stationary portion of the girt bar so that the slide/raft can be removed from the floor fittings. The stationary portion of the girt bar is designed to have a chamfer where the end of the trigger locking mechanism contacts a portion of the girt bar. The trigger locking

---

[3] Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01, PB2000-917002, adopted June 27, 2000.

[4] NTSB Safety Recommendations A-99-99 through-103

mechanism is also designed to have a 7 degree cutback.

> The investigation revealed that the 2L telescopic girt bar was improperly chamfered. When the door was opened in the "armed" mode, the force of the door opening apparently caused the trigger locking mechanism to slide over the improperly chamfered surface, which allowed the telescopic end of the girt bar to retract within the stationary portion of the girt bar. This retraction allowed the aft end of the girt bar to slip from its floor fittings and rotate forward. The movement and the weight of the slide/raft pulled the forward end of the girt bar from its floor fitting and caused the uninflated slide/raft pack to separate completely from the airplane and fall to the ground.

As a result of the investigation, the Safety Board issued two urgent safety recommendations to the FAA.[5] The Board recommended that the FAA issue and emergency airworthiness directive to require operators of overwater equipped A319, A320, and A321 airplanes to inspect girt bars for compliance with design specifications, perform a functional test, and replace girt bars that do not conform to specifications or pass the functional test.

You may obtain more detailed information about these Safety Board products by visiting the NTSB's web site. The safety studies and safety recommendation letters are available in their entirety at www.ntsb.gov.

The views expressed in this paper are not those of the National Transportation Safety Board and are not necessarily endorsed by the Safety Board.

Unified System Safety Model
For Global Flight Operations

Thomas A. Waldeck (MO4599), Flight Operations System Safety Analyst

Thomas A. Waldeck has over 40 years of experience in aviation, most of which was with The Boeing Company. Before retiring in 1995 he worked in flight test, safety, and aerodynamics. During that time he participated in each stage of an airplane's lifecycle, from conceptual design on through to supporting flight operations Since retiring he has been constructing a safety model that clearly presents some of the key lessons learned during the first century of flight that must be passed on to the next.

Abstract

An essential task for safe flight has always been to identify and reduce each unacceptable risk. Although the fundamentals remain the same, this task keeps becoming more complicated primarily due to the amount of information that must be understood to prudently consider each risk related issue. A necessary step in this safety improvement process is making sure the tools needed to assimilate and analyze this vital information are also improved. Each specialized discipline has, for the most part, done this relative to their area of responsibility. Now the tools necessary to integrate each of their findings need to be improved.

The improvements needed to assist those responsible for integrating each of these findings are: first, an improved method of recording each combination of events known to pose a risk; next, an improved method of determining which of these sequences are most likely to occur; and the third, an improved method of making sure each improvement nets an overall gain in safety. A tool specifically designed to assist in this manner is the fault tree analysis technique. This paper presents an overview of how a flight safety model based on this technique can assist those working to improve cabin safety. From this application, one can see how this model will similarly assist those working to improve each of the other areas of flight safety. The key to making any such safety model work is standardization and making sure its scope encompasses the complete world of flight safety, thus the name, Unified System Safety Model.

Introduction

The Unified System Safety Model (USSM) is a logical way of mapping the sequence of events, which can result in a flight operations accident. The model is constructed by systematically diagramming each sequence in the same manner as it would be described. Basically, that is as a series of events wherein either event A OR event B must occur or event A AND event B, depending on how that part of the sequence logically occurs. By diagramming each sequence in this manner, the model produces a map that clearly shows the combination of events we collectively know can result in an accident.

All too often our collective understanding of how an accident sequence can occur is not clearly pieced together until - after the fact. Fortunately, we each do know, in part, how these sequences can occur. Like a mosaic, now all that is necessary to get this composite view of each risk, before the fact, is to piece these parts together. The USSM is a formal attempt to create this composition.

This paper gives an overview of the part of the model that deals with cabin safety. The purpose of the model is two fold. First, to provide a standardized comprehensive means of capturing the lessons we each have learned about how different aspects of an accident sequence can occur. Second, to formulate a means of assessing how each preventive measure now in place to prevent each such occurrence is or is not working.

Model Concept

The Unified System Safety Model starts by depicting the top undesired event we are all trying to prevent, a *Fatal Flight Operations Accident*. The model pieces together what each of us knows about how this event can occur based on the fault tree analysis technique. This technique was developed as a logical way to analyze the risks of a large system when conventional means could no longer reasonably account for the many possible combinations of events.

The objective of a such a collective risk analysis is the same as it has always been, which was perhaps best stated in this 1938 *Western Flying* magazine article:

"Jerome Lederer of Aero Insurance Underwriters, read a most thorough discussion of "Loss Prevention in Civil Aviation" in which he not only classified the risks and hazards of aviation, as to their importance, and frequency, but suggested the means by which these risks may be reduced." (See Reference 1)

It is important to explicitly note two aspects of Lederer's risk analysis which pertain to all such analysis today. The first is that in order to understand a risk it is necessary to know not only how that risk can occur but also the chance of its occurring (frequency). The second aspect is that it needs to be thorough.

What has changed is the number of possible sequences and the volume of data that now must be included in such an analysis. The fault tree technique uses the same divide and conquer approach used to solve many problems of this type, for example, the equations of motion for a flight simulator. There the process starts with the most basic equation which describes this motion (Figure 1).

Figure 1: "Divide & Conquer" The Equations of Motion

$$\vec{F} = M\vec{A}$$

$$F_X = \text{Thrust} - \text{Drag} - \text{Weight Component}\ldots$$

$$\text{Drag} = \text{Drag}\,\alpha + \text{Drag}\,\beta + \text{Drag}\,\delta_{SPOILERS} + \text{Drag}\,\delta_{ELEVATOR}\ldots$$

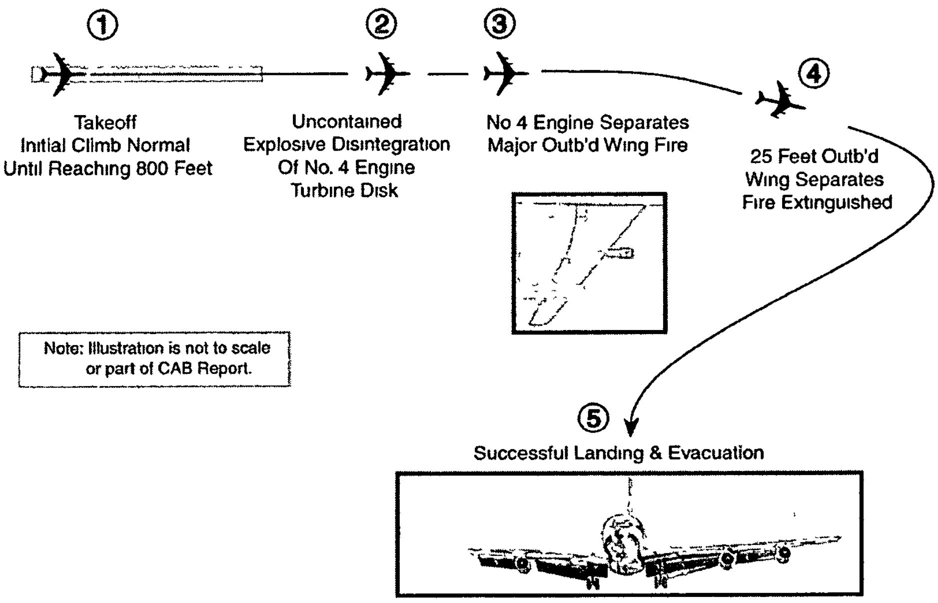
$$\text{Drag}\,\alpha = \text{Table Lookup } f(\alpha, \text{Mach No.}, \ldots)$$

Recognizing that these terms cannot be directly determined, the analyst proceeds to systematically subdivide each term until reaching a level where the terms can be determined, while preserving their mathematical relationships.

The fault tree modeling technique proceeds in the same manner. The model begins with the top undesired event and systematically subdivides it into sub-events until reaching a level where the events can be determined, while preserving their logical relationship. In both applications, the equations of motion and the fault tree, each subdivision has to be small enough to ensure that the sub-set is complete and that all terms are depicted in correct relationship to one another. Reaching this level of detail is important because if we stop short and only provide a generalized description of the events involved, such as *human error*, the specifically needed improvement is not identified.

Perhaps the best way to see the level of detail the model needs to achieve is to look at an actual accident sequence. Such an accident is illustrated in Figure 2, based on this author's understanding of the accident report (Reference 2).

Figure 2: Example Accident - PAN AM B-707, San Francisco CA USA, June 28, 1965



The synopsis of that report follows:

A Pan American World Airways, Inc., B-707-321B, N761PA, experienced an explosive disintegration of the third stage turbine disk of the No. 4 engine at approximately 1410 P.d.t., June 28, 1965. The accident occurred shortly after takeoff from San Francisco International Airport, San Francisco, California, at an altitude of about 800 feet above the ground. Disintegration of the turbine disk was followed by a fire in the No. 4 engine area and an explosion in the outboard reserve fuel tank. The No. 4 engine and approximately 25 feet of the right outer wing separated from the airplane.

The fire was extinguished and a successful emergency landing was accomplished at Travis Air Force Base, California, with no injuries to the 143 passengers or 10 crewmembers aboard the flight.

The board determines that the probable cause of this accident was a failure of the third stage turbine disk. This failure was caused by a transient loss of operating clearance between the third stage disk and the third stage inner sealing ring. This loss of clearance resulted from a combination of improper turbine rotor positioning during engine assembly, the use of serviceable worn parts, and an operating clearance which was less than predicted in design analysis.

The first thing that strikes you when looking at this report is that there were no injuries. Not just to those onboard, but also on the ground. Then follows, "Was it luck or skill"? For this particular accident there were many things that had to go right to preclude fatal injury. To name a few:

- Maintaining airplane control.
- Putting and keeping the fire out.
- Confining the wing explosion
- Safely evacuating all onboard

In each, it is fair to say there was the element of chance that occurred in everyone's favor. But also, a number of vital decisions were made which improved the odds measurably, beginning with the conceptual design and going on through to those made that afternoon by the flight crew and others.

The model must therefore not only capture what went wrong, but also what went right, and deal with the probable nature of each. In addition, certain improvements have been made to reduce the likelihood of a reoccurrence, and they too must be clearly depicted.

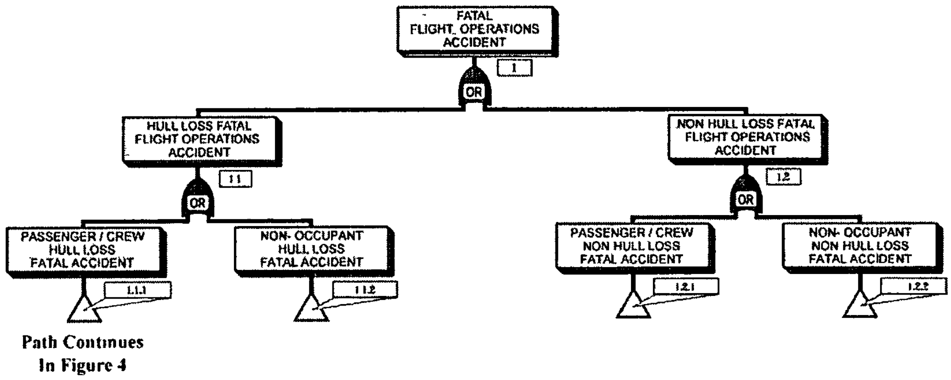
In the above accident, three events had to coexist to create the interference which weakened the engine turbine disk to the point where it disintegrated. These were the mispositioning of the rotor **AND** the reduced actual operating clearance **AND** the additional rearward deflection of the inner sealing ring caused by the use of worn vanes. The way the fault tree technique preserves the logical AND relationship described here is by connecting these events with a symbol that represents this logic, an AND gate.

The ignition source for the wing/engine strut fire was stated in the report as either the engine exhaust **OR** hot turbine parts **OR** arcing from exposed electrical leads. These events would therefore be connected with an OR gate. There are many risk management aspects to each of these logic gates. However, to understand the modeling concept presented here, it is sufficient to simply read the event relationship noted on each symbol as it appears. (For more information on logic gates, see References 3 through 5.)

First Subdivisions

The top undesired event is first subdivided into those events involving a hull loss and those not involving a hull loss as shown in Figure 3. Each of these events is next subdivided into those fatal to passenger/crew members or those fatal to non-occupants. The OR gate used to connect these events can be seen to be just as one would verbally described their sequential relationship.

Figure 3: Top Undesired Event First Subdivisions



These sub-events were selected in order to accurately assess the different risks that can occur in each event, even though in some cases they may be precipitated by the same hazardous event. An uncontained engine explosion is just such an event. Although each branch benefits from all efforts to prevent this type of engine failure, each branch also provides additional opportunities to further improve safety by reducing the way an engine explosion can inflict fatal injury in that particular branch.

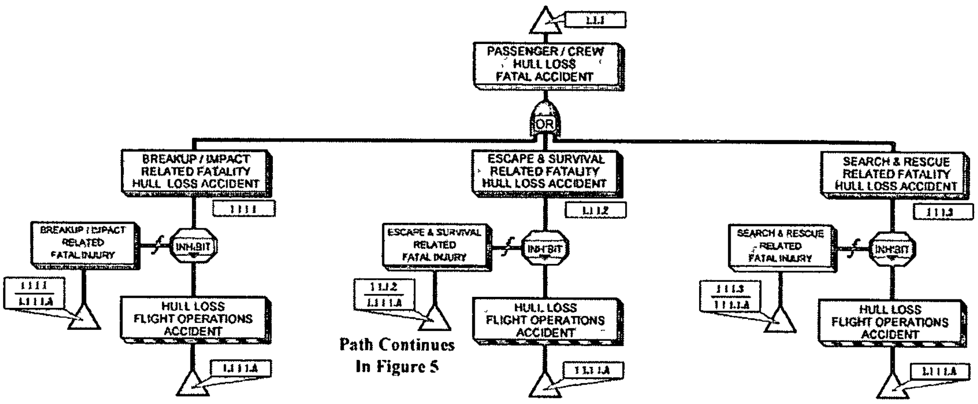
This brings up the second reason for constructing the model in this manner, to ensure a net gain in safety results from each proposed improvement. For example, to minimize the risk to those on the ground following an engine explosion, it may be proposed to divert to a remote field. However, a number of other considerations influence whether this diversion would result in a net gain in safety. The model must show how each such proposal impacts each of the other branches shown here. In the above accident example, the report discusses some of these very trades the crew went through in deciding where it would be best to land.

In addition to the risks directly associated with an explosion per se, the model must also address other indirect risks which can accompany such an event. These include distractions, stress and the state of urgency that may severely limit the time to think through each option.

The logical structure of the model gives it the ability to accurately account for an event that appears in more than one sequence. We will follow the *Passenger/Crew Hull Loss Fatal Accident* path shown in Figure 3 to illustrate how this accounting takes place with respect to some of the events that directly relate to cabin safety.

The *Passenger/Crew Hull Loss Fatal Accident* event is first subdivided according to the steps necessary to survive a hull loss accident. These are: first, to survive the breakup/impact if there is one; next, to escape; and finally, to be rescued. The consequences of failing to complete each of these steps define the next three events depicted in Figure 4.

Figure 4: Passenger/Crew Hull Loss Fatal Accident



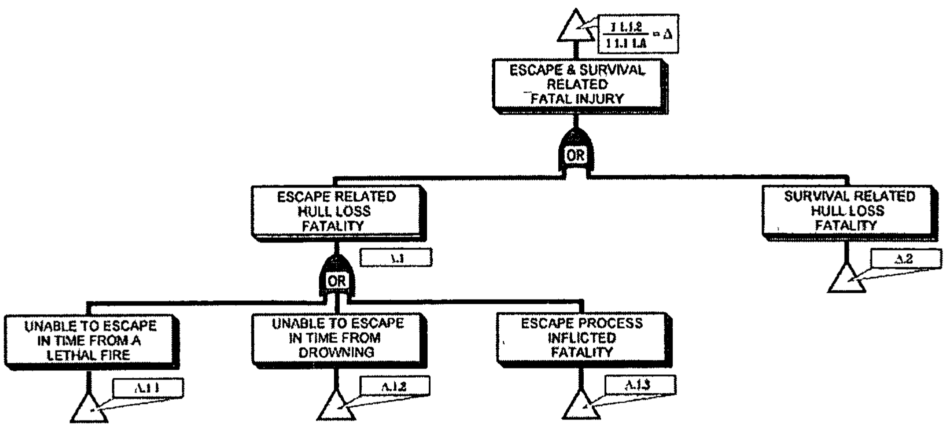
Next the USSM depicts how each of these three events can occur. Each requires a *Hull Loss Flight Operations Accident* AND a condition that can inflict fatal injury. Such an AND relationship is referred to as a Conditional AND. It is depicted using a special type of AND gate called an INHIBIT, as shown in Figure 4. The reason it is depicted in this manner is to clearly show the condition which allows that path to continue and therefore the task before us, how to minimize the likelihood of this condition occurring.

The letter "f" shown next to the three INHIBIT gates in Figure 4 is a shorthand notation to indicate that these conditions are a function of the type of *Hull Loss Flight Operations Accident* which occurs. One can appreciate that the escape conditions accompanying a landing overrun depend on the conditions off the end of that runway, i.e., an embankment, water or a prepared surface. Therefore, the risk of fatal injury associated with escape must take these conditions into account. With any AND situation you need to follow both paths to understand that particular risk. We are going to focus only on the *Escape and Survival Related Fatal Injury* path as it relates more directly to cabin safety.

Escape and Survival

The *Escape and Survival Related Fatal Injury* event is first subdivided into its two fundamental parts, escape and survival (Figure 5). The *Escape Related Hull Loss Fatality* event is next subdivided into three broad classifications of conditions that can inflict fatal injury. These are fire, drowning and the risks inherent in the escape process itself.

Figure 5: Escape & Survival Related Fatal Injury



Path Continues In Figure 6

One of the challenges in describing each subset is semantics. Where possible, illustrations are provided to supplement the limited word descriptions in each event box. The model also provides a menu option for each event, which will be described later. Another challenge is deciding if an event is significant enough to be included in a particular path. For example, exposure to Non-flammable Hazardous Materials was a condition that was not thought to possess a significant enough threat to be included here. One of the advantages of this modeling technique is that if later it is decided that an event should be included, it can be added with minimal impact upon the rest of the model.

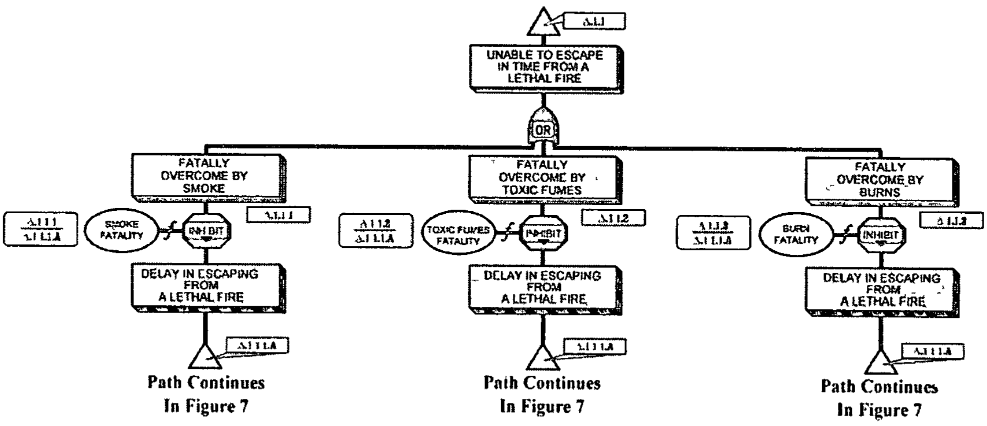
We will next follow the *Unable To Escape In Time From A Lethal Fire* branch (Figure 5) to show how the model reaches the level of detail required to assess this aspect of the overall escape risk. The *Unable To Escape In Time From Drowning* branch develops very similarly. The third branch shown in Figure 5, *Escape Process Inflicted Fatality,* involves risks inherent in the escape process itself, e.g., falling from an open exit. This branch shows some of the other risks a pilot must weigh before ordering an evacuation in the face of an uncertain fire threat. The way the USSM diagrams this decision making process is discussed in the Human Factors Related Event section to follow.

The event, *Unable To Escape In Time From A Lethal Fire,* is first subdivided into three broad classifications of how a fire can inflict fatal injury; namely, by smoke, toxic fumes or burns (Figure 6). As a fire threat may exist at this point in the accident sequence, the model next looks at the essence of such an encounter - is there sufficient time to escape.

The two events that determine if there is sufficient time to escape from a fire are the amount of time it takes to escape AND, given that amount of time, the likelihood a fire will ensue that can inflict *Smoke, Toxic Fumes* or *Burn* related fatal injury. The time it takes to escape is referred to as *Delay In Escaping From A Lethal Fire.* The three INHIBIT gates shown in Figure 6 depict the consequences if this delay is too long relative to each of these fire hazards. Again, the reason for this breakdown is that each path provides different options for reducing that type of fatal injury risk.

Eventually the model reaches a point where either another model or modeling technique is needed to further define the likelihood of that event occurring and/or the event becomes hardware, software, or user specific. Such is the case here for determining how *Smoke*, *Toxic Fumes* or *Burn* related fatal injuries can occur. The "global" model stops at this point and defines each of these conditions as a basic input. They are depicted with an elliptical event box (Figure 6) to designate that type of input.

Figure 6: Unable To Escape In Time From Lethal Fire Threat



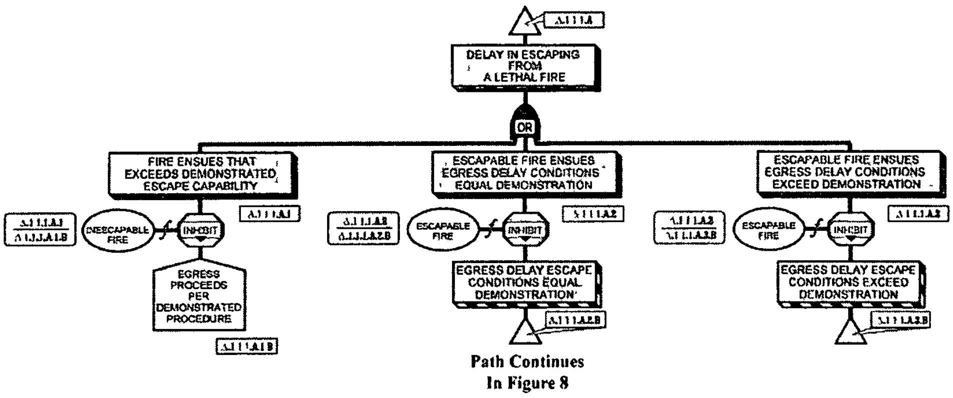
At first, it may appear that the global model is stopping short of its goal. However, what we will find is that at this level the risks associated with each of these input events is, in most cases, well understood and has been analyzed in considerable detail for some time. This is the case for *Smoke*, *Toxic Fumes* and *Burn* related fatal injuries. Therefore, this point marks the logical place to delineate between the global model that shows all the risks and the local model that shows the particular aspects of a risk.

For the *Delay In Escaping From A Lethal Fire* event (Figure 6), the model first distinguishes between three cases that determine how much time can be afforded:

- Inescapable fire.
- Escapable fire with egress conditions equivalent to demonstration.
- Escapable fire with egress conditions that exceed the demonstration.

These sub-events are depicted in Figure 7. The first, an *Inescapable Fire*, is defined as one that exceeds the demonstrated escape capability. In this case, egress is proceeding per the demonstrated procedure, however, the fire ensues at a rate that precludes all occupants from reaching safety. Most efforts to mitigate the risks in this branch therefore must focus on ways to prevent a fire from starting or spreading this rapidly.

Figure 7: Delay In Escaping From Lethal Fire



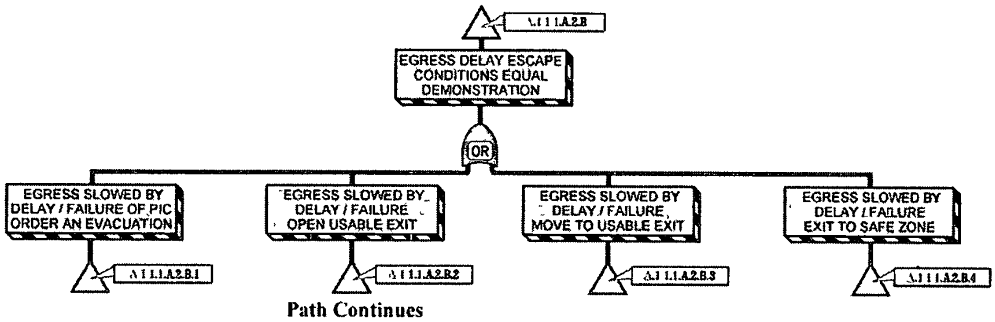
The second and third cases concern *Escapable Fire* situations, i.e., if egress proceeded as demonstrated, all would have had time to escape. The second case looks at ways the escape process can be delayed under conditions equivalent to those used for the demonstration. The third case looks at escape conditions that exceed those used for the demonstration, for example, if someone is incapacitated.

Here we will continue with the middle event, *Egress Delay Escape Conditions Equal Demonstration.* This event is first divided into four major steps involved in executing an escape under conditions equivalent to those used during the demonstration; namely;

- Initiate an evacuation order
- Identify and open all safe exits
- Move to nearest opened exit
- Egress and collect at a safe zone

In each, time is of the essence, as shown in Figure 8. The model next looks at what can cause a delay in each of these events. To make sure each source of delay is included, the model must examine each element of the escape sequence from start to finish, even though it is not feasible to include each element in the demonstration. The first sub-event shown in Figure 8 is a case in point, the time it takes the Pilot-In-Command (PIC) to order an evacuation. The model must replicate (as best it can) the process the PIC must go through to issue an evacuation order. Here we have come to the first primarily human factors related event, which must be further subdivided as it is still too general.

Figure 8: Egress Slowed By Escape Fault With Fire Threat



Path Continues In Figure 9

Human Factors Related Event

The way the USSM logically diagrams each human factors related event is to first depict the specific task involved and then the action required by each participant. The specific task in this case is for the PIC to initiate an evacuation order if warranted in the most timely manner possible. Keep in mind, the emergency conditions in this path are equivalent to those used during the egress demonstration and involve a hull loss accident. The action required by the PIC is to notify the designated crew members of the decision s/he has reached.

The model next divides each such encounter into three principle stages a person goes through to perform any such action:

1. **Perception** - does a serious fire threat exist.
2. **Decision** - is an immediate emergency evacuation the best course of action.
3. **Response** - notify designated crew members via the means provided.

Each stage involves a uniquely human process with various degrees of consciousness, memory recall and internal feedback, as well as finite limitations and individual variance. The ability to perform each stage also is influenced by other tasks and environmental factors, which encompass not only those that have a physiological effect, but also a psychological effect.

The model next systematically looks at the risks inherent in each of these stages that can delay an evacuation order. Each risk is diagrammed in context of the other tasks present and environmental factors which may exist. Space precludes showing how each such risk is systematically identified. However, a brief look at these stages will illustrate how necessary it is to decipher each *human error* code entry in this manner in order to understand how any delay can be minimized.

For the risks associated with perception, the model first looks at each of the human sensors which is, or should be, inputting the needed vital information. Each sensor first requires a detectable signal level, next recognition, and finally awareness as to what information needs attention. An example of a visual recognition risk is an illusion. There are also situations where someone remote from the flight deck perceives the fire threat first. The PIC must perceive this fire threat via a communication link. In addition to the time involved in establishing such a link, there are the risks associated with communicating the nature of the fire threat. For each such risk, the model depicts the lessons learned with regard to emergency communication links, standard phraseology, and acknowledgments.

After the PIC perceives a fire threat exists, an evacuation decision needs to be made. This decision process can run the full gamut of possibilities. The decision can vary from allocating priority to another safety concern after deciding that a significant fire threat does not exist to immediately ordering an evacuation having perceived a serious fire threat. The decision can be delayed by the need to consider a conflicting evacuation risk, e.g., the risk inherent in the escape process itself. In each such case the time required for cognitive reasoning depends on the procedures, training and related personal experience of the person involved. The increasing scarcity of the latter puts more emphasis on capturing the lessons learned from previous emergencies. The model provides a useful audit tool for verifying that the procedures and training now in place reflect this cumulative experience.

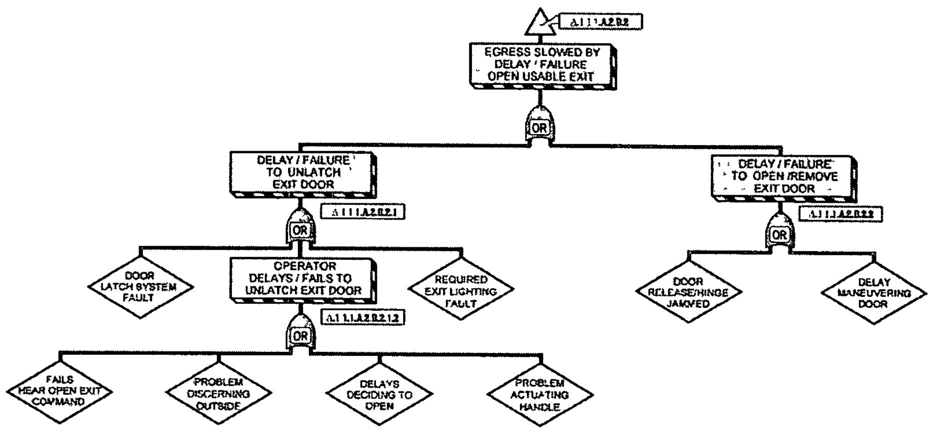
The last stage an individual goes through to perform an action is the response itself. The response in this case is normally an intercom call to the designated cabin attendant. One of the risks applicable here is an unintended response referred to as a slip, for example if the call to evacuate is made over the wrong communication link. The ergonomics of the communication system, as well as familiarity with a previous console, can greatly increase the likelihood of this type of slip occurring. Another risk is to unintentionally leave a critical word out of a verbal response. Again, the model provides the structure to depict where standard phraseology, acknowledgement and specific training are needed to reduce the likelihood of this event occurring.

Here, the global model has again reached the point where another modeling technique is needed to further analyze each of these particular human factors related risks. Considerable progress has been made in understanding each of these particular perception, decision and response risks. Although there is more to be understood, this is not what is limiting our ability to reduce the number of human error code entries. What is lacking is a global map that clearly shows where each specific human error or human limitation risk resides and the consequence thereof. This is based on the fact that when they are discovered as the result of an accident or serious incident, they are, for the most part, readily understood and resolved. The USSM is designed to specifically show where each known human factors risk resides and to track whether these resolutions are effective.

Cabin Safety Input Event

We will next look at a part of the escape sequence risk that takes place in the cabin, *Egress Slowed By Delay/Failure Open Usable Exit,* (Figure 9). This event is somewhat unique in that as a passenger the task to open an exit could be yours the next time you fly, provided you are able and willing. As simple as this task may appear, actually performing this function in an emergency has its share of challenges, even for trained cabin attendants (References 6 and 7).

Figure 9: Egress Slowed By Delay/Failure To Open Usable Exit



The model first looks at two separate tasks involved, unlatching the locking mechanism and then removing or rotating the door to its open position. Each of these events is then divided into the basic inputs denoted by the diamond events shown in Figure 9. The first basic input event accounts for a delay due to a mechanical failure of the door latch.

The next event, *Operator Delays/Fails To Unlatch Exit Door* (Figure 9), is a human factors related event and is therefore subdivided in the same manner as described above. The perception stage in this case involves the following: perceiving that it is time to commence opening the door, perceiving if it is safe to open that exit, and after deciding if what you perceive warrants opening that exit, perceiving where the unlatch handle is. This event has to be assessed for both trained cabin attendants and untrained passenger operators for each type of applicable exit.

This is sufficient detail to understand how the USSM systematically maps each of the risks that impacts escape. A retrace, starting with Figure 3, also reveals the number of risks we did not discuss in detail. Together, these figures readily show the magnitude of the tasks involved in managing cabin safety. The only feasible way to manage such a number of events is to "divide and conquer" each in this manner.

To further assist in managing each risk the model presents the following four menus for each event:

Definition Menu - The first part of this menu explains the meaning of this event in detail noting how it differs from the other events in that sub-set and also noting alternate terminology. The second part references key articles or reports. The third part describes how our understanding of this event has evolved, and in particular, how this evolution might influence previously recorded information.

Occurrence Menu - This menu provides access to the information needed to estimate the chance of that event occurring. The first part lists the accident and incident findings in which this event has occurred. The second part lists available sources who have operational data which shows the frequency with which this event has occurred. The third part references analyses, tests or simulations performed to determine the likelihood of this event occurring. For basic AND gate input events, this menu also provides the information needed to estimate how long an occurrence is likely to last.

Requirement Menu - This menu references which part of each requirement, standard, regulation, specification, etc., is applicable to this event (if any) and how compliance is assured. It also cross references the entry(s) in the Occurrence menu which this requirement is intended to prevent.

Improvement Menu - The first part of this menu presents a chronology of the flight safety improvements applicable to this event. The second part lists those improvements that have not been implemented and the reason why, if possible. The third part references ongoing research and states what additional research is needed.

The USSM does not contain most of this information. It provides the location where this information can be obtained. That is why a standardized global address for each event is essential. To initiate this concept, a prototype could be built to link and disseminate all accident and serious incident data now available in the public domain. Such a prototype would provide a valuable service by making those parts of each such report readily available when that subject is being discussed, be that during design, maintenance, training or flight operations.

Summary

The fault tree technique gains its strength from the old adage, "divide and conquer". The Unified System Safety Model logically subdivides the whole safety threat in a systematic manner until arriving at the level of detail where either another modeling technique is needed and/or the model becomes hardware, software, or user specific. At that level each such event is given a specific address. Only in this manner can one be assured that each known risk is being accurately accounted for.

At first, the task of keeping track of this many events may appear overwhelming. However, the process is really quite straight forward. It is similar to a mailing address, albeit simplified, in that the global model provides the equivalent of the country, province and city while the local models provide the street and the location thereon. For the most part, we have excellent local maps for each part of each risk sequence. Lacking is a global map which shows how all these parts come together and create the risks on tomorrow's flights. The Unified System Safety Model is specifically designed to provide this view.

References

1. Jerome Lederer, *Safety in the Operation of Aır Transportation*, Presented at Norwich University, Northfield Vermont, April 20, 1939. (Copy available at the Flight Safety Foundation Library)

2. CAB (Civil Aeronautics Board) Aircraft Accident Report: *Pan American World Airways, Inc. B-707-3212B, N761PA San Francisco CA, June 28, 1965*

3. W. E. Vesely, F. F. Goldburg, N. F. Roberts, D. F. Haasl, *Fault Tree Handbook*, U. S. Nuclear Regulatory Commission, NUREG-0492, 1981

4. Salvatore J. Bavuso, et al, *HiRel: Hybrid Automated Reliability Predictor (HARP) Integrated Reliability Tool System (Version 7.0)*, NASA Technical Paper 3452 Volume 1 through 4, 1994.

5. Laura L. Pullum and Joanne Bechta Dugan, *Fault Tree Models for the Analysis of Complex Computer-based Systems*, Annual Reliability and Maintainability Symposium ISSN 0149-144X, 1996.

6. National Transportation Safety Board, *Flight Attendant Training and Performance During Emergency Situations*, Special Investigation Report, PB92-917006, NTSB/SIR-92/02, June 9, 1992

7. National Transportation Safety Board, *Emergency Evacuation of Commercial Airplanes*, Safety Study, PB2000-917002, NTSB/SS-00/01, June 9, 1992

附錄十三

人為因素調查方法之探討

Guessing Why Before Determining What
Hypothesis Generation
In
Data Gathering for Human Factors Investigations

By

Randall J. Mumaw, Ph.D.
Human Factors Specialist
Boeing Commercial Airplanes, Seattle, USA

Guessing Why Before Determining What:
Hypothesis Generation in Data Gathering for Human Factors Investigations

Randall J. Mumaw, Ph.D.
Human Factors Specialist - Boeing Commercial Airplanes, Seattle, USA

Randall J. Mumaw is a cognitive psychologist who supports flight deck human factors for Boeing Commercial Airplanes. His areas of interest are system design and evaluation, human error, decision making, training, and cultural influences on safety

Peter Renshaw (CP0092)
Air Safety Investigator - Australian Transport Safety Bureau, Canberra, Australia

Peter Renshaw is a registered psychologist who holds pilot licenses on fixed-wing and rotary-wing aircraft. He has also taught aviation psychology and human factors at the University of Western Sydney and Swinburne University of Technology. Peter is currently employed by the Australian Transport Safety Bureau (ATSB)(formerly the Bureau of Air Safety Investigation (BASI)), as a Transport Safety Investigator (Aviation) – Human Performance

Thomas Wang
Air Safety Investigator - Aviation Safety Council, Taiwan, Taipei

Thomas Wang is serving as the SQ006 Accident Investigation Human Factors Group Chairman. He is a former China Airlines A300 First Officer He has a Masters of Aeronautical Science, Flight Safety and Operations from Embry-Riddle Aeronautical University, and a Masters of Control Engineering, National Chiao Tung University.

Yei-Yu Yeh, Ph.D.
Associate Professor, Department of Psychology
National Taiwan University, Taiwan, Taipei

Professor Yeh has a Ph.D. from the University of Illinois-Urbana/Champaign. Her specialties are in human attention and performance, advanced display concepts, and human memory.

Abstract
Human performance has been shown to be a significant contributor to aviation accidents and incidents in a large percentage of cases. Fortunately, theory of human performance and error has been advancing to a point where we can often develop valid accounts of the behavior of those involved in the mishap. Extensive data gathering is required to guide the development of valid accounts. Due to the wide range of issues that may be relevant, we believe it is necessary to tie hypothesis generation tightly to data gathering. Hypothesis generation serves to create initial accounts of human performance that indicate the set of data that may be relevant to the investigation. In this paper we argue for a more formal hypothesis-generation process that is conducted in short, iterative cycles with data gathering in the first few months of the investigation.

The Emerging Importance of Human Factors Analysis

Recently, the authors have been involved with the crash of a Boeing 747-400, operated by Singapore Airlines, at Chiang Kai-Shek Airport near Taipei, Taiwan. The airplane lined up and took off on a partially closed runway, striking construction equipment. The crash resulted in 83 deaths and complete loss of the airplane. We are the nucleus of the human factors team, and we are collaborating on this accident investigation with groups investigating flight operations, airplane systems, CVR/FDR, Air Traffic Services, etc.

Over the last 10-15 years, it has become more common to have a team focused on human factors (or have human factors specialists distributed to teams), and generally, the importance of human factors as a discipline has increased. Clearly, if one looks at accident investigations from 20-30 years ago, one finds that the human performance issues were not addressed in the detail they are today. There has been progressive refinement in analyzing communication and coordination among participants, organizational influences, flight crew management skills, etc. However, even today there are differences across investigation agencies in the extent to which they document human performance issues. A number of good examples can be found of human performance issues being analyzed more in-depth and becoming central to the accident investigation, including the following:

- a recent report by the Australian Transport Safety Bureau on the Qantas 747-400 runway overrun in Bangkok in 1999 is one good example of how human performance issues have become more central to the accident investigation.
- the Air Accidents Investigation Branch (Great Britain) 1990 report on the British Midlands 737-400 accident near Kegworth in 1989, especially the discussion of the flight crew decision making on engine loss.
- the Bureau Enquetes-Accidents (France) report on the 1994 Tarom Airlines accident in Paris.
- the National Transportation Safety Board (US) report on the Valujet in-flight fire contains a detailed analysis of the maintenance side of operations.

Several larger forces have increased the prominence of human factors in accident investigation. First, there has been wider recognition of the role of human performance in the full range of aviation mishaps (recovered errors, incidents, accidents). There is the oft-quoted finding (e.g., Helmreich & Foushee, 1993) that roughly 70-80% of all accidents include human error as a primary contributor (across operational settings; not just in aviation). A second, but equally important influence, is that psychology and the applied disciplines of human factors and industrial engineering have done a better job of describing human performance. We now have detailed theories of both skilled performance and flawed performance (error). Certainly, debates still exist—e.g., in the extreme, some researchers want to eliminate the notion of human error completely due to the uncertainty that often exists in complex operational settings (Woods & Cook, in press). However, there are a number of widely accepted theories of how undesired behaviors can occur in operational settings. The theoretical framework of Reason (1990) has led much of this work in aviation.

More specifically, theories of human performance have helped us understand the following:

- Perceptual illusions (e.g., "black holes") that can occur and lead pilots into dangerous situations (see Kraft, 1978).
- The types of action and memory slips that can occur, and the potential effects of distractions and interruptions (Norman, 1981; Dismukes et al., 1999)
- The role of maintaining situation awareness (SA) and how loss of SA can lead to a "mistake." Mistakes are different from slips in that pilots and technicians perform correct actions given their understanding of the situation; however, they have an incorrect belief about the current situation.
- The constant struggle between meeting both productivity goals and safety goals, which can be in conflict. Examining this issue, in turn, reveals how organizations can create subtle but powerful disincentives for safe performance.

- The role of the design of interfaces between humans and technology as aviation has relied more on automated systems.
- Powerful performance-shaping factors such as fatigue, weather, and time pressure (e.g., see NTSB, 1994).

A skilled human factors team can apply this knowledge to construct informative accounts of how undesired human behaviors were elicited and led to a tragic outcome. Indeed, recent analysis at Boeing (Shontz, personal communication, June, 2001) attempts to go beyond the flight crew actions to explore the types of cognitive errors that likely occurred.

Of course, the point of detailed explorations of human performance is to go beyond a single behavior in an accident scenario to identify system elements that could compromise safety in the future (e.g., poorly designed and confusing procedures, organizational incentives to ignore safe operation, equipment interfaces that fail to lock out inappropriate actions). The primary objective of accident investigations is addressing these elements in order to reduce this risk of accidents in the future.

Prescriptions for Data Gathering in a Human Factors Investigation

Accident investigations traditionally have been divided into an initial phase that focuses on establishing basic data or facts of the event (we'll call this the **data-gathering phase**) and a later **analysis phase** that seeks either a probable cause or set of failures or critical factors at the heart of the event. The intent of this division into two phases is to ensure that a full picture is established before analysis begins. The concern is that analysis can influence or bias data gathering; or that analysis would proceed without a full understanding of the facts. These are legitimate concerns. However, in practice, especially for human factors investigations, we believe it is not just difficult but unwise to attempt to conduct these two phases as distinct and serial. Our experience in the SQ006 investigation has fostered this belief.

A recent ICAO document (ICAO, 1993) provides prescriptions for how a human factors analysis should be conducted. A primary focus of this document is identifying a rudimentary data set regarding human performance and the state of those involved in the mishap (e g., flight crew, air traffic controllers, maintenance technicians). This data set captures the sequence of events; behavioral, cognitive, emotional, and physiological conditions of relevant operational personnel; their recent histories (72 hours to 2 weeks); and the task and environmental conditions that may have influenced their performance—a simple description of the surface of the event. Often, as recommended in the ICAO document, the driver of this initial data gathering is a human factors inventory, such as the SHEL model (Hawkins, 1987). This type of inventory lists possible influences on human performance from several perspectives (e.g., social, cognitive). Not all of these performance issues will apply to each event, and it is up to the human factors team or investigator to determine which issues are relevant.

Depending on who survives the accident, it may not be possible to complete the recommended data gathering. And, even in the best circumstances, the accumulated data from these initial queries will rarely provide a complete account of the accident. The analysis phase will require a deeper look at the event and those involved in it. We, and others before us, have found that, in addition to the inventory-driven data set, it is essential to begin creating hypotheses about how the event occurred to aid in identifying other relevant data. That is, creating accounts of how human performance may have been influenced or shaped in the event.

Why is the rudimentary data set insufficient at this stage? Because human performance is incredibly complex, and the range of issues that could affect performance is broad. Not all will be relevant, and there is no simple approach to determining which of these issues will be relevant prior to exploring the event.

The Role of Hypothesis Generation

What is the legitimate role of hypothesis generation in the data-gathering phase?

Hypothesis generation allows one to construct coherent accounts of the event that can begin to reveal potential error mechanisms and performance-shaping factors. It is not sufficient simply to list potential influences; the key to a useful human factors analysis is to describe precisely how human performance was pushed into an undesirable region—e.g., how a flight crew ends up long and fast on approach. With more detailed theories of human performance, we can provide a more detailed account of the type of "error" that occurred and what elements in the system may have elicited that error.

As hypotheses are generated (as possible accounts are proposed), they allow the investigator to determine the broader set of relevant data. Then, in each case, the investigator needs to determine (with impartiality) whether there are sufficient data to support that account. This reasoning leads to further data gathering. These data, in turn, will aid the investigator in evaluating the worth of each hypothesis, and some potential accounts will not be supported.

This form of analysis allows the investigator to develop a clear rationale concerning what specific information might be useful, why certain individuals should be interviewed, and how these individuals can assist the investigation. Moreover, any organizational examination of an operator, regulatory authority, service provider, manufacturer, or other party must be well-considered and well-planned to avoid premature or counterproductive inquiries.

Further, this process helps in linking the performance of agents during the event up to broader system issues. The ultimate goal of the investigation is to determine these system issues: determine whether policy or design changes are needed, whether training needs to be modified, whether infrastructure needs to be updated, etc. The hypothesis creates these links through local influences on human performance to system drivers of those influences.

The reaction to our desire for an earlier role for hypothesis generation is likely to be, "Yes, it is important to generate hypotheses, but that is the role of the analysis phase." We offer two responses to this comment. First, human factors data (e.g., eye witness accounts) may be more perishable (than other types of data) as time passes. It is not unusual in the investigation of a major accident for the formal data-gathering phase to last three months or more. Critical information regarding human performance is often captured through interviews with those involved, and interviews can be seriously compromised during this delay. For example, memory of events fades or is altered by listening to other accounts. The deterioration and contamination of eyewitness accounts has been well documented (e.g., Loftus, 1996; Loftus & Hoffman, 1989). Also, as time passes, larger forces—unions, airlines, manufacturers, the media, politicians—can begin to push agendas that can distort the results of interviews with survivors. In addition, organizations can begin to respond to perceived problems, changing policy and structure, and thus eliminating the conditions that existed at the time of the event. There is often no physical evidence, as there is with airplane wreckage, that preserves the trail of human performance. The critical facts are often extracted from the knowledge, impressions, and mental states of those involved. These artifacts are fleeting and vulnerable to the passing of time. Therefore, data gathering needs to be completed quickly.

A second response is that it is hypothesis generation that needs to determine when data gathering is complete It is not possible to judge the completeness of data gathering without knowing the range of hypotheses that should be considered. The model should be one of short, iterative cycles, not distinct and serial phases of activity. Initial data gathering leads to hypotheses, which lead to broader data gathering. Later activities, in turn, help to eliminate or enrich hypotheses, and perhaps lead to further data gathering.

Reducing the Threat of Contamination

While we believe that this shift to short, iterative cycles is essential for developing accurate and complete accounts of human performance, we also understand why there is concern about mixing data gathering and hypothesis generation. It is both a strength and vulnerability of human cognition to construct narratives—to create coherent stories about how events unfolded. It is important to point out that the generation of narratives will occur whether hypothesis-generation activities have formally commenced or not. These narratives, once formed, become powerful shapers of later reasoning. One type of error that has played a significant role in a number of major accidents is confirmation bias, which is the tendency to seek evidence that confirms one's mental model and discount evidence that fails to fit it (Nisbett & Ross, 1980)

However, formal representations of the event as it is understood can be effective countermeasures to confirmation bias. By carefully documenting both the hypotheses that are being thought through and the data captured to date, investigators can better remain detached from any particular account. They are better able to consider the implications of each narrative and weigh it against what is known.

Currently, we do not know of any national accident investigation group taking this approach to data gathering in commercial aviation. If hypothesis generation is allowed to go forward as part of data gathering, it is carried out informally. In discussions with a human factors professional at a major aviation accident investigation group, one author was told that they expand data gathering by following issues that seem interesting. Perhaps this group and others are more systematic than is suggested by this in laying out and evaluating hypotheses; our experience, however, doesn't suggest it is. More formal analysis methods are described (e.g., in the ICAO document) but these are reserved for the analysis phase.

A more formal and systematic process that lays out hypotheses (or narratives) would benefit investigators by allowing everyone to see how well the existing data support (or don't support) each hypothesis. Further, the hypotheses become competing accounts of the existing data.

Another consideration is the participants involved in the two phases. Typically, the team put together for the data-gathering phase includes representatives from the airplane manufacturer, the airline, and others who may have conflicted interests in the final form of the analysis. The analysis phase, however, often involves only members of the neutral/independent investigating agency to protect analysis from being influenced by the conflicted participants. If this approach is desired, we believe this is still possible. We are not advocating that the formal analysis phase be eliminated, only that elements of what is thought of as analysis be brought into the data-gathering phase. The formal analysis phase can still exclude the conflicted participants to avoid undue influence.

Nothing New or Something to Fear

We anticipate two possible reactions to the preceding comments. One possibility is that readers will say, "This is nothing new. Everyone is aware that data gathering needs to be closely tied to hypothesis generation. The distinction between data gathering and analysis is artificial and overplayed."

Indeed, some sense of this is subtly conveyed in the ICAO document. However, what is critical to emphasize is that this process needs to be formal. Given that the data-gathering phase on major accidents is typically a team activity, a well-documented process is needed to ensure that understanding is shared by all team members. It is almost impossible to develop this shared understanding without some formalism.

The other possible reaction to our suggestion is, "Oh my God, you're suggesting we bring hypothesis generation into the data-gathering phase. This can only contaminate the data-gathering process, which must proceed fully without bias."

Our reaction to this is that this position is not practical for two reasons. First, as stated earlier, humans are unable to continue to gather data for an extended period without establishing narratives for context on their own. These narratives are powerful organizing tools. Thus, if the narratives are going to be developed, it is best to document them and expose them to the light of day. The potential for biases will also become known through this exposure.

The second reason, as described earlier, is that the range of human factors issues is so broad, it is not possible to identify the full set of relevant data without establishing a context through hypothesis generation.

Summary

Human performance is likely to be an important element of most aviation accidents and incidents. Fortunately, theory of human performance and error has been advancing to a point where we can often develop valid accounts of the behavior of those involved in the mishap. Our claim in this paper is that the data-gathering phase of the human factors investigation needs to be closely linked to the development of hypotheses about human error and performance-shaping influences. We propose that a more formal hypothesis-development and tracking process be included to guide data gathering. A formal process can enable one to identify relevant data in a timely manner and also guard against biases being introduced into data gathering.

References

Air Accidents Investigation Branch (1990). Report on the accident to Boeing 737-400 G-OBME near Kegworth, Leicestershire on January 8, 1989. Farnborough, UK: Dept of Transport.

Australian Transport Safety Bureau (2001). Boeing 747-438, VH-OJH Bangkok, Thailand. (Investigation Report 199904538). Canberra, Australia: ATSB.

Bureau Enquetes-Accidents (1995). Report on the incident on 24 September 1994 during approach to Orly to the Airbus A310 registered YR-LCA operated by Tarom.

Dismukes, K., Young, G., & Sumwalt, R. (1999). Cockpit interruptions and distractions. *Flying Safety, 55(6)*, 16-20.

Hawkins, F.H. (1987). *Human factors in flight.* Gower Technical Press.

Helmreich, R.L., & Foushee, H.C. (1993). Why crew resource management? Empirical and theoretical bases of human factors training in aviation. In E.L. Wiener, B.G. Kanki, & R.L. Helmreich (eds.) *Cockpit Resource Management.* San Diego, CA: Academic Press.

International Civil Aviation Organization (1993). Human factors digest No. 7: Investigation of human factors in accidents and incidents. (Circular 240-AN/144). Montreal, Canada: ICAO

Kraft, C.L. (1978). A psychophysical contribution to air safety: Simulator studies of visual illusions in night visual approaches. In H. Pick, H.W. Leibowitz, J.R. Singer, A. Steinschneider, & H.W. Stevenson (eds.), *Psychology from Research to Practice.* New York: Plenum.

Loftus, E.F. (1996). *Eyewitness testimony.* Cambridge,MA: Harvard University Press.

Loftus, E.F., & Hoffman, H.G. (1989). Misinformation and memory: The creation of new memories. *Journal of Experimental Psychology. General 118(1)*, 100-104.

National Transportation Safety Board (1994). A review of flightcrew-involved major accidents of U.S. carriers, 1978 through 1990 (NTSB/SS-94/01). Washington, DC: NTSB.

National Transportation Safety Board (1997). Aircraft accident report in-flight fire and impact with terrain Valujet Airlines flight 592 DC-9-32, N904VJ, Everglades, Near Miami, Florida May 11, 1996 (NTSB/AAR-97/06). Washington, DC: NTSB.

Nisbett, R., & Ross, L. (1980). Human inference: Strategies and shortcomings of social judgment. Englewood Cliffs, NJ: Prentice Hall.

Norman, D.A. (1981). Categorization of action slips. *Psychological Review, 88*, 1-15.

Reason, J. (1990). *Human error.* Cambridge University Press.

Woods, D.D, & Cook, R.I. (in press). Perspectives on human error: Hindsight bias and local rationality. In F. Durso (Eds.), *Handbook of Applied Cognitive Psychology*, Wiley.

附錄十四

鳥擊案件 － 迷思與真相

Bird Strikes - Myths and Realities

By

Al Weaver

Bird Strikes

Myths and Realities

Abstract

This discussion deals with the historical aspects of bird ingestion hazards into large transport commercial aircraft operating worldwide. The history starts with the advent of jet powered transport aircraft in the early 60's through the 90's. In this 30-year period many lessons were learned both relative to the hazard (bird behavior) and the response of the aircraft and engines that it threatens. The discussion considers the design and certification requirements that have evolved over this 30-year period and the lessons learned which drove the changes currently in place today. In spite of the changes in the design tolerance of the engines, there is a recognized existence of a large bird flocking hazard which will remain beyond the design expectations of the engines for many years to come. The discussion provides recommendations for minimizing this future shortfall.

About the Author

Al Weaver designed and conducted the first bird ingestion tests into commercial jet engines in the early 60's in support of demonstration criteria for the FAA. He was instrumental in supporting the FAA data collection efforts to define the bird ingestion hazard and the response of the engines to this hazard since 1980. Mr. Weaver was the industry chairperson for recommending changes to the design and testing standards for these engines culminating with the recommendations to the FAA and JAA for updating these standards worldwide.

Al is retired from Pratt & Whitney and currently teaches gas turbine accident investigation techniques at Southern California Safety Institute

When jet engines were first introduced into commercial service in the early 60's, there were little formalized standards for bird ingestion capability. The engines were tested to show that they would not catastrophically fail such as being uncontained or catching fire. There was no formal requirement to continue running and to deliver power following the abnormal occurrence of an ingestion event. In spite of this informality, the engines installed on most DC8, B707, B720 behaved quite well and did continue to produce safe power even after ingesting multiple birds in flock encounters.

However all outcomes were not totally successful and some events did involve multiple engine powerloss and/or runway overruns leading to serious aircraft damage. This prompted the FAA to issues more formal requests to the manufacturers to demonstrate in their development testing that the new large engines being introduced for the B747, the DC10 and the L1011 would continue to produce power for a short period of time following the ingestion of two seagulls.

Shortly after the introduction of the large bypass engines in the early 70's numerous events of multiple bird ingestion were documented resulting in multiple engine powerloss albeit with a successful outcome. In spite of the ultimate successful outcome (takeoff aborts or forced landings) there was a clear recognition that more universal and formal standards for design and testing of engines needed to be applied. This evolved into a need to collect data against a standard format and in the total worldwide environment that these engines operate within.

At the end of this data collection effort it was recognized that there was a variance in the hazard throughout the world and a variation of an order of magnitude in the successful response of the engines to this hazard. The latter was a lesson learned for the manufacturers since it demonstrated that some the product capability would respond to reasonable design changes within current technology. In other words each manufacturer had so called Achilles heels for different causes. The hazard variation demonstrated that Mother Nature and variations in airport control standards could combine together to produce bird flocks beyond what had been anticipated in the design and certification standards.

In the end of this study, recommendations were made to more uniformly apply the lessons learned in habitat management, while at the same time raising the bar in the certification testing to more likely catch the weaker engine designs.

The basis of the recommendation towards raising the bar in certification testing, was the recognition that the variability in the ingestion encounter itself (with a fixed size and quantity of bird encountered) was leading to large variations in the outcome for a given engine design. This variability in encountered ingestion parameters, combined with the impracticality of guaranteeing the mechanical outcome following very large bird ingestion. Taken together all manufacturers recognized that they could not design and certify an engine under one set of test conditions for all possible encounters in service. What then should a reasonable standard be, that could be demonstrated as "good enough" under the tight constraints of an engine design/development program.

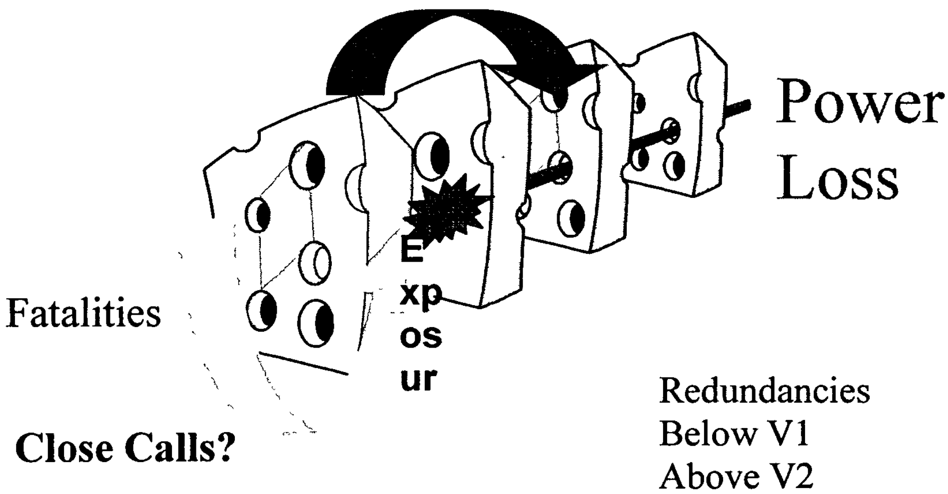
Comparing current aircraft safety risks from a historical perspective developed the answer. It was seen that only one confirmed fatal accident was to be attributed to bird ingestion alone exceeding the mechanical ability of the engine in the 30 years of large jet transports (B737/DC9 and larger transport). From a data validity standpoint, numerous other incidents of serious aircraft flight impairment could be documented resulting in a risk of a serous outcome occurring at roughly one in 10 million engine departures (E-7) at the worst. It was decided that it would be practical in a short period of time (one engine generation) to improve these odds by a factor of 10. Such an improvement in risk over such a large size of fleet would necessarily entail a major impact on the design standards and performance. Since the, majority of the impact was to be against the engine structural strength, it was obvious that this increase in structural ability would entail some sort of aerodynamic penalty when applied to the engine blading. Such an aerodynamic penalty has as one of its outcomes the unregulated ability of engine fuel efficiency (other possible outcomes, such as EGT, stability, and/or thrust are often regulated to some sort of standard within the FARs)

It was estimated that the impact of raising the bird ingestion standard to effect a factor of ten improvement in safety could be absorbed in a next generation engine without reducing the fuel efficiency of the engine. However this may have prevented offering greater improvements in fuel efficiency to the operator.

The current state of the bird ingestion hazard has attracted many groups searching to propose further improvements. These proposed improvements have taken the form of increased standards in the design and/or increased control to airports or their environment. Both of these avenues have been examined to a fine detail in the past 20 years. There is little argument that there is room for improvement in both venues, however the justification and prioritization for these benefits Vs their impact and costs does need t be examined in much more detail.

The initial justification that their have been many near catastrophes, needs to be quantified in light of standards means of characterizing safety of flight. The best standard of characteriziation regarding engines, is contained in the FAA approved Continued Airworthiness Assessment Methodology (CAAM). This methodology sets forth levels of safety loss from 1 to 4. Where "4" is an accident by most definitions and 1 is a minor incident with intact levels of redundancy available to protect the flight or outcome. The “Reason” model graphically illustrates this measurement technique.

Flight Outcome is a Combination of Many Factors



Redundancies
Below V1
Above V2
Gross weight
Number of engines
Degree of power loss

As has been stated earlier, the worst period of historical risk involved a near accident or level "3" risk level of 1 in ten million flights. The current standard for the engines being certified today expects to improve this risk by a factor of ten to better than 1 in 100 million for a level 3 event. This performance level needs to be examined against other flight safety risks, which are also competing to be addressed from the same industry resources. These other risks when taken together are contributing to a system wide risk level of 1 in ten million for accidents alone (CAAM level 4) and many times worse than that for level 3 events. Clearly those groups who attempt to steer us in the direction of improved flight safety must consider a prioritization.

This is not to suggest that enough have been done about the bird hazard. Clearly there are many lessons learned, some of which have not yet been employed universally. The problem solution has however moved from the simple fix of design to one of merging the interests of many groups within or near aviation. This will probably be more a problem of communication and understanding than a purely technical solution. As examples of this challenge for communication and understanding consider the following:

Who Are the Stakeholders?

Pilots

- Should they notify the airport tower of the presence of bird flocks?

Airport Tower

- Should they shutdown any runway where birds greater than 1 Lb. are on the ground within XX meters?

Regulator

- Should they expedite FAR/JAR rule updates without a delay of 25 years of product/environment changes?

Public

- Should they be educated that it is not nice to fool with Mother Nature by encouraging increases in bird populations?

附錄十五

巴黎戴高樂機場跑道撞機失事調查

Collision
between
an MD83 & a Shorts 330
at
Roissy Charles de Gaulle Airport
On
May 25th, 2000
By

Pierre Jouniaux & Franck Giraud
BEA, France

Collision between an MD83 & a Shorts 330 at Roissy Charles de Gaulle Airport On May 25th, 2000

1. Introduction

At the end of the evening of 24/25 May 2000, at Paris Charles de Gaulle, the unusual traffic increase caused by the return of Spanish supporters from the Champion's League Final was decreasing. An MD83 full of supporters, ready for takeoff at the runway 27 threshold, received takeoff clearance. In sequence a Shorts 330 was cleared to "*line up runway 27 and wait, number two*". The tower controller believed that the two aircraft were heading in sequence for the runway 27 threshold though an intersection was given by the ground controller to the Shorts for takeoff. The Shorts entered the runway as the MD83 was reaching V_R. The tip of the MD83 wing penetrated the Shorts cockpit and injuredthe two pilots, one fatally. The MD 83 aborted its takeoff.

Working groups were set up to cover the following topics:

- airport ATC,
- airline operations,
- aircraft,
- flight recorders,
- airport infrastructure.

On June 30th 2000, a preliminary report presenting the first factual information was issued. Pilots and ATC experts were associated to the working groups and contributed to the writing of the report.

The final report was published at the end of July 2001.

2. Scenario

On the evening of 25 May 2000, the context at Paris Charles de Gaulle aerodrome resulted from a combination of Standard arrangements and of characteristics specific to the night of 24/25 May 2000.

Concerning the standard arrangements, the usual configuration at night is that the entire ATC team is on duty in the north tower only. Since the beginning of their operations at Roissy Charles de Gaulle, Streamline Aviation twin turboprops have usually taken off from a runway intersection

The specific characteristics were that on the night of 24/25 May 2000, there was extra activity as a result of a large number of flights to Spain. Works near runway 27 led to the closure of several taxiways. There was a lot of lighting in the works area and movements

by worksite vehicles. The LOC position was occupied by a controller, an instructor at the National School of Civil Aviation (ENAC), who was on recurrent training at Paris Charles de Gaulle. Since the beginning of the evening, no aircraft had used taxiway 16 for runway 27 take-offs.
This context had created, for the LOC controller, an erroneous perception of the situation at the aerodrome, according to which all aircraft having to take off from runway 27 were directed towards the runway threshold. As he had not noticed the indication of the taxiway on the strip and nothing had drawn his attention to the peculiarities of the Shorts' situation, in his mind he was sure that this aircraft was taxiing behind the MD 83.

Nothing subsequently disturbed his false mental picture. A direct visual check was difficult to perform because of the works and the light pollution and radar verification was difficult because of the screen's characteristics. In addition, bearing in mind his mental picture of the situation, there was no reason for his attention to be drawn to taxiway 16. The content of the radio communications with the Shorts indicate that there was no identification of position on the LOC frequency.

The controller instructed the MD 83 to line up on runway 27 behind a B 737 which was landing. The B 737 vacated the runway via taxiway 10 in front of the Shorts.
At this stage, the controller had a mental picture of the Shorts at the holding point of the threshold runway 27. Thus he authorized the MD 83 to take off and, in the same sequence, he gave the Shorts clearance to line up, with the instruction " *line up runway two seven and wait, number two* ". This incorrect instruction, since the Shorts was on taxiway 16, corresponded to the controller's perception of the situation.

The crew of the Shorts hadn't understood the takeoff clearance given in French to the MD 83. Because of the very sharp angle between the taxiway and the runway, they could not see the beginning of the runway, which was behind them while they were taxiing on taxiway 16. Reception of the line-up clearance caused an immediate reaction and they began to taxi towards the runway whilst wondering about the identity of the « number 1 » aircraft.

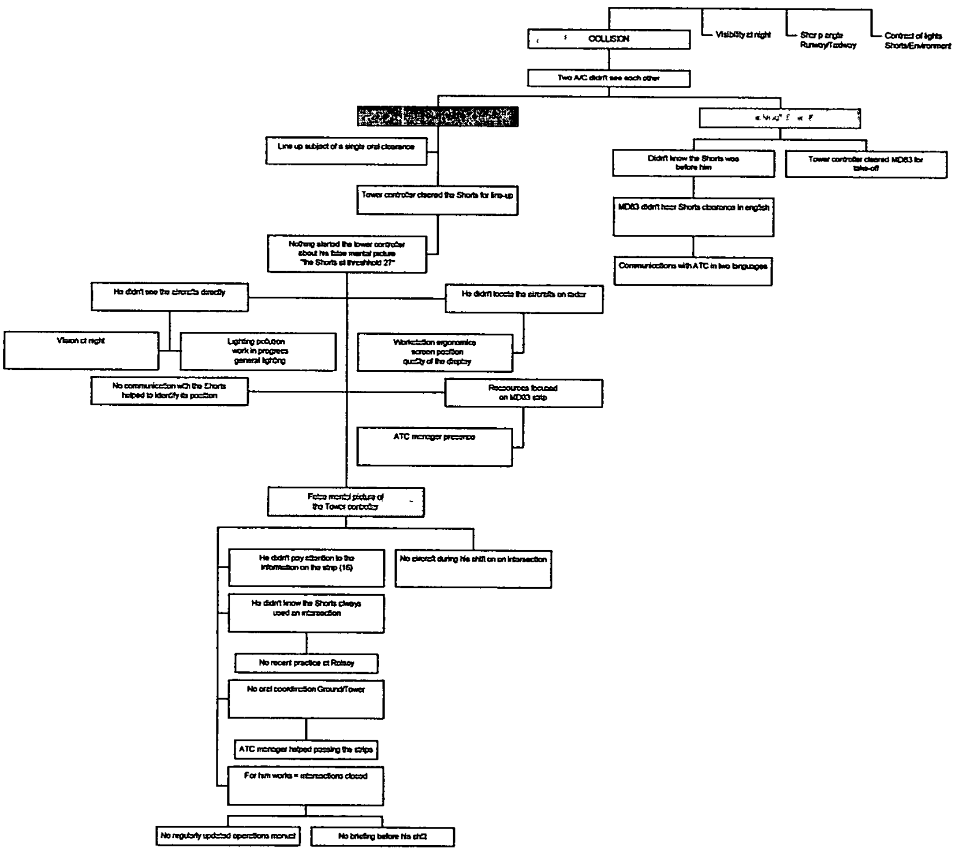
Meanwhile, the crew of the MD 83 could understand the line-up clearance given to the Shorts but the words used made it impossible for them to know that this aircraft was going to line up in front of them. In addition, at brake release, there was no obstacle in front of them.
Visual contact between the aircraft was established very late in a situation where an avoidance manoeuvre was no longer feasible.

3. Method for Analysis.

A pitfall we had to avoid in this investigation was to focus on the peculiarity of the context. It is true that there was more traffic that night at Roissy Charles de Gaulle. But at the time of the accident it was decreasing and the traffic was more like what it was usually at night. One can also notice that the tower controller was familiarizing himself again with the airport as he spent the majority of his time an ATC instructor at the Toulouse training center. This was not directly pointed out in the causes of the accident (some issues had been however raised about the return into service and the information for the personnel). Also works were in progress near the runway 27 threshold. The investigation showed that they did not contribute to the accident, though a lack of information on their precise extent to the ATC staff was identified.

First of all we would like to underline the fact that the recollection of the events by the particpants was very helpful. Of course, for various reasons, the perception of each of them was different. But even these differences give an idea of the perception of the different participants and provided valuable indications to the investigation. This led the BEA investigators to focus on two main issues, which were the reason why the collision was unavoidable after the wrong clearance was given to the Shorts and what led the tower controller to give an incorrect clearance to the Shorts.

Following this logic, a fault treewas built which is reproduced below :



This method was useful to obtain an in-depth analysis of the accident as well as to facilitate the encoding of the event under the ADREP 2000. format which now allows us to address human factors issues. Indeed, this method allows us to address failures under the SHELL model which is used in the ADREP. The use of the Reason model would not have been as efficient. However, we think that this method does not apply to all occurrences. We were here dealing with an accident with a central cause and a large number of contributory factors and above all the accident can be described in one single sequence several subevents. However we think that each time it is possible, this kind of approach is worthwhile and can bring satisfactory results.

4. General Phraseology concerns

The investigation highlighted many aspects related to phraseology, or at least the practice of radio-telecommunications. For the understanding of the sequence of events, it was important to check if the pilots and the controllers used the standard phraseology. To check this, both national and international documents where used: ICAO doc. 4444 and the French RCA.

The investigation proved that pilots and controllers used a standard phraseology. Anyway, the comparison of the national and international texts revealed some discrepancies. Moreover failings of international references were noticed concerning some procedures used that night.

4.1. Line up "in sequence"

The phraseology analysis showed that the local controller was, in his mind, lining up his aircraft "in sequence", which corresponds to a procedure. This must imply that all the aircraft are supposed to take-off from the threshold. Such a procedure is not defined in the French national RCA nor in ICAO documents. This procedure is used all over the world, mostly to speed up traffic flow, but its use is only tolerated.

Lining up aircraft "in sequence" consists of giving the clearance to an aircraft to enter the runway at its convenience, and in most of the cases a long time before the aircraft actually enters the runway. This has the effect on the controllers of distancing themselves, in their mind, from the problem of the line up: the crews manage their line up, and the controller only has to give the take-off clearance.

4.2. Mention of the holding point

The ground controller has to coordinate a departure from an intermediate taxiway with the local controller, but it appears that this coordination is done very soon after pushback. Then, the following clearances are "Taxi holding point 27" or "Line up runway 27". They no longer mention which holding point it is. In the case where there are intermediate taxiways, a conflict can appear. This uncertainty appeared to be critical in many cases of airprox in France and worldwide.

4.3. Multi-language usage at international airports

The crew of the Shorts, who were not French-speaking, did not understand the MD 83's clearances to line up then take off. In addition, it was obvious to them that this message was not meant forthem.

The investigation found no evidence that if theMD83 clearance had been given in english, the Shorts crew would have understood the discrepancy with their own clearance..
It is obvious that there is a real issue about dealing with two different languages on the same frequency and the debate on this subject in France is far from over.

5. International cooperation

The investigators found it important to compare the French situation with practices in nearby countries and asked different countries tocontribute. Actually, our nearest European colleagues shared information with the BEA about their ATC standards, and this cooperation helped to better recommand improvements to our standards.

This cooperation is very important because the resources developed in each country are different. Regarding departures from intermediate taxiways, some countries found solutions by regulating such departures (Visibility conditions, etc..). Others implemented technical means to assist controllers (stop barriers).

Unfortunately, International structures for feed back concentrate on the technical aspects on ATC, and not on human factors questions..

6. Conclusion

This accident, just after it occurred, was considered by the French aeronautical community as a single ATC error. The faults tree showed that malfunctions appeared at many levels, and improvements (je ne comprends pas ici - PS).

In our report, the BEA issued fourteen safety recommandations about phraseology, language and ATC organization. These recommandations will be adressed by the French DGAC in the next few months but since their scope impacts the international community, it remains very important for safety that everyone be aware of the conclusions and recommendations.
The complete report is available on the BEA's web site: http://www.bea-fr.org.

附錄十六

航空器空中相撞調查技術

Using Physical Evidence From A Mid- Air Collision

By
Keith McGuire
Northwest Regional Director, NTSB

Using Physical Evidence From A Mid- Air Collision

Keith McGuire, M02416, Northwest Regional Director, NTSB

The views expressed in this paper are those of the author and not necessarily the views of the NTSB.

Keith McGuire is the Director of the National Transportation Safety Board's Northwest Regional Office. A former pilot with the US Air Force, Keith has a B.A. in Physics, an M.A. in Counseling Psychology and has completed the Senior Executive Fellows Program at Harvard University.

Introduction

The mid-air collision is one of the classic aircraft accident types that will continue to confront professional investigators. Although there have been advances in technology that have reduced the potential for this type of accident, they have not been eliminated and it is probable that aircraft accident investigators will continue to investigate this type of accident in the foreseeable future.

Historically, many of the mid-air collisions which occurred in visual conditions were concluded with some type of a finding which said there was a "failure to see and avoid" on the part of both pilots. However, a thorough review of the facts of the accident may have resulted in completely different findings. Unless we know that a pilot was physically capable of seeing the other aircraft and that there was sufficient time to react to a sighting, a "failure to see and avoid" is not an accurate finding. This paper is a review of the way physical evidence can be used to assist the investigator in accurately determining the factors involved in a mid-air collision.

Why use the wreckage?

There are potentially many sources of information for determining the headings of the two aircraft and therefore determining the mid-air collision angle. Witness statements are a source of general information about the collision but tend to vary and are usually not very precise. However, they can frequently be helpful in determining general directions of flight and approximate attitudes of the two aircraft. If you are fortunate enough to have two flight recorders, the problem is solved very easily. Likewise, reliable radar data will provide an excellent source of historical flight track information. It should be noted, though, that while the radar data can be quite accurate, it does not always show avoidance maneuvers which may have happened during the last few seconds. In addition, it records the track of the two aircraft rather than their headings. However, when combined with valid physical evidence, the combination can provide an excellent picture of the collision sequence. The radar data provides historical information and the physical evidence provides a picture of the collision itself. Of course there will be situations where the physical evidence is the only data available. In that case, the analysis of the scratch marks will be the only basis for determining the collision angle.

A new approach to the on-scene investigation

The techniques developed in this paper vary somewhat from Appendix 11 of the Fourth Edition of the ICAO "Manual of Aircraft Accident Investigation". The ICAO manual, for example, refers to 19 "Rules of Thumb" that provide guidance for analyzing scratch marks. While these "Rules of Thumb" are valuable, this paper will develop a framework for analysis of scratch marks that is easier for the investigator to remember and use while at an accident scene.

Wherever possible, the terms in this paper are consistent with those in the ICAO Manual. The basic terms and their relations are summarized in the drawing in Attachment A. This drawing comes from the ICAO manual and is supplemented with the identification of the convergence angles. It should be noted that the convergence angles are always equal to the angle the scratch mark forms with the longitudinal axis of the aircraft. This makes it very easy to solve for the collision angle when both of the aircraft have discernable scratch marks.

The collision angle is the angle between the flight paths of the two aircraft.(1) This angle is the one commonly referenced in most publications. The other two angles in the triangle, the convergence angles, are probably of greater usefulness to the investigator. The convergence angle tells us the visual difference between the aircraft heading and the approaching aircraft. In other words, the convergence angle is the how far left or right the pilot would have to look to see the other aircraft. If the speeds and headings of the two aircraft remain constant, both convergence angles will also remain constant. In this condition, the converging aircraft will appear motionless to an observer on the other aircraft. Since the human eye sees relative motion sooner than a stationary object, this helps to explain why pilots do not as readily see aircraft on a collision course.

It is important to note that the convergence angles have to be based on heading rather than track in order to establish a valid visual perspective for each pilot. Once these angles are established, you can replicate the visibility from a cockpit with fairly good accuracy. A visibility study can be done with a computer to provide a graphical plot of what the pilot(s) could have seen from the cockpit. The pilot's visibility can also be assessed manually by reconstructing the pilot's seated height and seat location in a similar aircraft and then determining what is at the convergence angle. If there is windscreen surrounding this point and there was no interference from the sun, we can conclude that the pilot had the potential of seeing the other aircraft. If there is structure in this location, we can start calculating when the size of the other aircraft would have been larger than the relative size of the structure and even calculate the time until impact. If the relative location of the converging aircraft was in a position normally not scanned, it is not reasonable to expect the pilot to have seen the other aircraft. Therefore, spending the necessary time to obtain the proper factual information will provide the investigator with much better insight into the actual circumstances of the accident.

Using scratch marks to determine the collision angle always gives a relative angle between the two aircraft headings rather than the actual compass headings of the aircraft. Similarly, the scratch marks may be able to tell you the relative attitude of one aircraft compared to the other but it will not give you the absolute attitude of either aircraft.

Locating and measuring a valid scratch mark

One of the critical aspects of using physical evidence is the selection of scratch marks. A valid scratch mark will always be straight and ideally will have a paint transfer from the other aircraft. The next criterion is to find the scratch mark on a horizontal surface. (A vertical surface must be used when calculating climb or descent) While it's possible to use scratch marks from a curved or non-horizontal surface and then convert them to an "equivalent" mark on a horizontal surface, the easiest marks to use come from a horizontal surface.

While it's preferable to obtain the scratch marks from the initial contact points of the two aircraft, this isn't always a necessity. However, the more direct the collision was the more important it is to use scratch marks from the initial contact. When the two aircraft do not significantly alter their flight paths during the impact, scratch marks made later in the collision can be used. Conceptually, changing the direction of a flying aircraft is a function of two variables. There is the force applied and the time that force is applied. The more direct the impact (force) or longer the contact (time), the more important it is to use scratch marks made early in the collision sequence.

Once a scratch mark has been located, it's direction and the angle it forms with the longitudinal axis of the aircraft (assuming once again that we are working on a horizontal plane) needs to be documented. The angle between the scratch mark and the longitudinal axis is the angle of interest for our calculations. However, it should be noted that if a scratch mark is measured with reference to the lateral axis, the angle it makes with the longitudinal axis can easily be calculated. The investigator only needs to find reliable scratch marks and accurately measure them reference an aircraft axis. The calculations for determining collision and convergence angles can be done later.

Methods of calculating the collision angle

There are several methods to determine the collision and convergence angles in a mid-air collision. The most basic approach is to use graph paper to plot out the track and magnitude (speed) of each aircraft. If all four of these values are known, they can be plotted and the angles they form measured. The advantage of this approach is that it does not involve mathematics and is easier for some people to understand. However, the significant disadvantages to this method are that you have to know all four values for the speeds and directions of both aircraft and the convergence angles may not be as accurate if they are based on the track of the aircraft rather than their headings.

Trigonometric functions allow the investigator to determine the collision and convergence angles using the Law of Sins and the Law of Cosines when only three of the four values for speed and heading are known. This approach is shown in Attachment B. This approach also allows for establishing reasonable estimates when only two of the four values are known, as illustrated in Attachment C.

It is important to note at this point that a common mistake made in evaluating a mid air collision is for the new investigator to assume that the scratch mark (or structure deformation) is synonymous with the track of the other aircraft. Investigators will sometimes find themselves sighting down the scratch mark as though that is where the other aircraft came from. Occasionally, even experienced investigators can be seen placing a part of an aircraft wreckage into a matching damage on the second aircraft as though that was the way the two aircraft collided. In reality, a scratch mark is a combination of the movement of two different bodies in motion. (See Attachment D) Only when one of the aircraft is not moving or the second aircraft is approaching from the 12 o'clock or 6 o'clock positions, will the scratch marks show the direction of travel for that aircraft.

The techniques discussed in this paper have been limited to determining horizontal angles of convergence and collision. However, the same techniques will work to establish the vertical angles of convergence by using scratch marks from vertical surfaces rather than the horizontal surfaces. The recommended technique is to do two separate sets of calculations, so that you develop the horizontal convergence angle and the vertical convergence angle separately.

Applying the theory in two different scenarios

When both aircraft have good scratch marks

When both aircraft have reliable scratch marks, solving for the collision angle is a fairly simple process. Since the scratch marks are the same as the respective convergence angles, it is simply a matter of subtracting the two scratch mark angles from 180^0 to get the collision angle.

When only one aircraft has a good scratch mark but the speeds of the two aircraft can be determined or estimated

When only one aircraft has a reliable scratch mark, it is necessary to have the speeds of the two aircraft in order to solve for the collision angle. While any estimate introduces some error into the final results, a range of probable speeds can be used and the resulting range of probable collision angles will provide useful information to the investigation. As can be seen in Attachment C, the variation in one general aviation accident was only about four degrees. While it's desirable to have more precise calculations, this range can still be very useful for a visibility study.

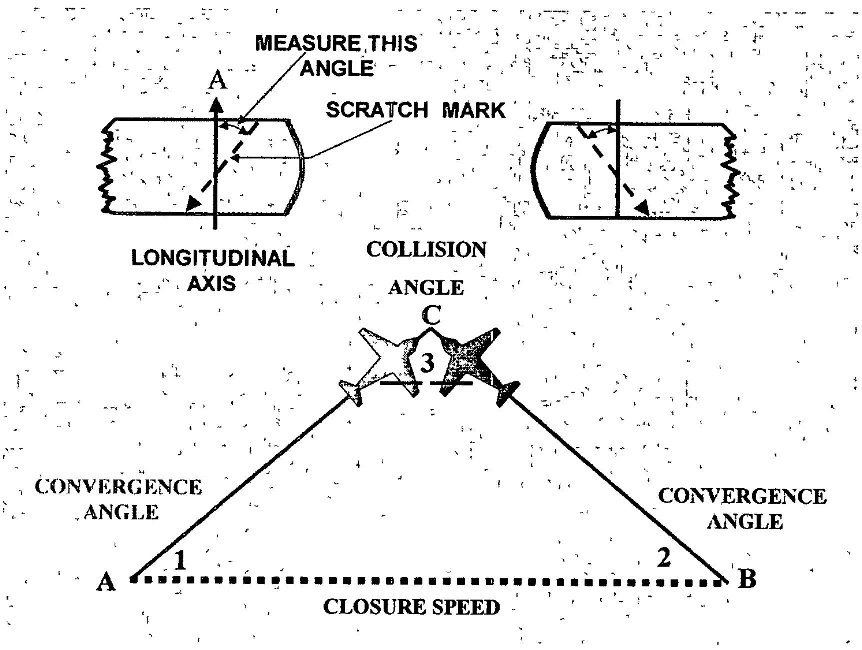
Summary

The aircraft wreckage from a mid-air collision can provide valuable information to the investigation process. The techniques in this paper provide a simplified approach to gathering and evaluating this physical evidence. If the investigator will properly document the scratch marks, then the collision and convergence angles can be mathematically derived.

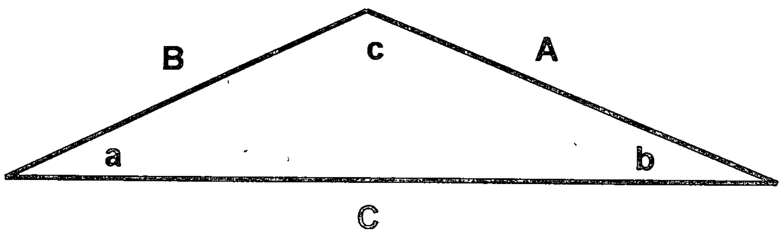
Notes

(1) While not significant to the subject matter, the collision angle as used in this paper is actually the difference between aircraft headings. This allows for consistency with the convergence angles that are developed from heading information.

Attachment A



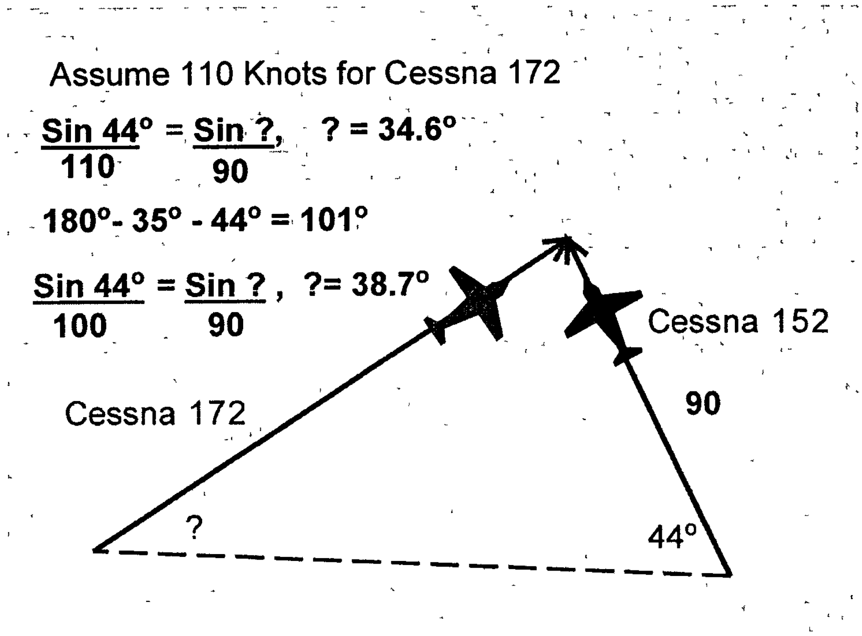
Attachment B



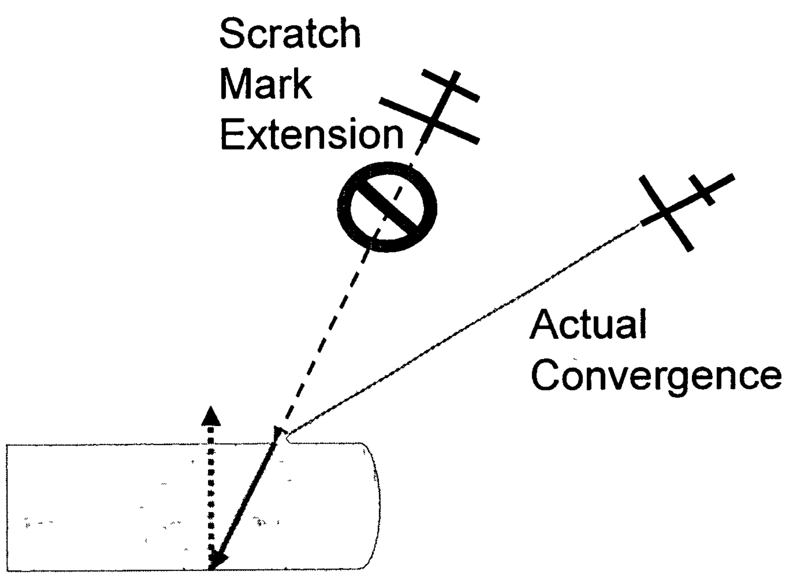
Law of Sines

Sin a/A = Sin b/B = Sin c/C

Attachment C



Attachment D



附錄十七

航空器儀表顯示錯誤與失事

Erroneous Instruments and Aircraft Accidents

By
Simon Lie
Air Safety Investigator
Boeing Commercial Airplanes

Erroneous Instruments and Aircraft Accidents

Simon Lie (AO4462)

Air Safety Investigator - Boeing Commercial Airplanes

Simon Lie has been with Boeing for 12 years. Before becoming an Air Safety Investigator, he worked on gust and buffet load analysis, central maintenance computer design and as a flight line engineer for 737, 747, 757, 767, and 777 airplanes. He received his bachelor's and master's degrees in aeronautical engineering from the Massachusetts Institute of Technology.

Abstract

A number of aircraft and many lives have been lost in accidents involving erroneous airspeed, altitude, or attitude information presented to flight crews on flight deck instruments. In all cases, the aircraft was capable of continued safe flight and landing following the instrument failure. Although the flight crews were in most cases aware that some of the information presented to them was erroneous; they did not use the remaining available information to safely complete the flight.

The defenses against accidents due to instrument error include elements of airplane system design and of crew training. Engineers can design systems to detect and/or prevent the display of erroneous information. Training programs can help crews correctly identify and respond to erroneous instrument readings.

This paper examines the event sequences for several accidents and incidents in an effort to identify common elements. These common elements are then described, followed by a discussion of how they have shaped and continue to shape the ongoing technical evolution of air-data and attitude instrument systems.

Introduction and Historical Perspective

The night of December 21, 1961 was cold in Ankara, Turkey. The temperature hovered near freezing and visibility was 2 km. The moon was full, but clouds covered three quarters of the sky. Snow was falling at 2340 local time when a De Havilland Comet 4B took off from Esenboga Airport bound for Nicosia, Cyprus. On board were 3 flight crew members, 4 cabin crew members, and 27 passengers. One to two seconds after takeoff, the airplane rapidly assumed an excessively steep climb angle, estimated to be between 45° and 50°. The airplane stalled with the left wing down at a height of about 450 feet and sank to the ground in a relatively flat attitude. Of those on board, only seven passengers survived, six of whom were seriously injured. The probable cause of the accident was the obstruction of the pitch pointer in the captain's director horizon which led him to make an excessively steep climb immediately following liftoff.()

Thirty-eight years later, on December 22, 1999, the moon was again full, but obscured by blowing mist and scattered clouds over London's Stansted Airport. At 1836 local time, a Boeing 747-200F freighter took off bound for Milan (Malpensa) Airport. On board the cargo flight were 3 flight crew members and 1 ground engineer. Thirty-seven seconds after takeoff, the airplane began a left turn as part of the departure routing. Eighteen seconds later, the airplane was pitched 40° nose down and banked left close to 90° just prior to impact with the ground. There were no survivors. The UK Air Accidents Investigation Branch (AAIB) is currently investigating the accident. The AAIB has determined that the commander of the previous flight reported that the captain's attitude director indicator (ADI) was unreliable and would indicate wings level during turns in either direction. Data recorded on the flight data recorder (FDR) for the accident flight and the previous flight show a constant roll attitude of around wings level.() The FDR records roll data from the same source that normally supplies the captain's ADI.

Although both of the above examples involve attitude instruments, there are numerous examples of accidents involving erroneous airspeed and altitude indication. When these accidents do occur, they are often catastrophic. Over the past ten years, accidents involving erroneous flight instruments have averaged 71.5% fatalities among those on-board. By contrast, the equivalent rate for all other hull loss and substantial damage accidents is 26.2%.()

After examining accidents involving erroneous flight instruments, it is possible to establish common elements of the accident sequences. These common elements represent the chain of events that must be broken to prevent future accidents. Since the time of the Comet tragedy, there have been significant advances made in the areas of airplane design and operational procedures in an effort to break that chain. This paper presents an overview of those advances as they relate to the common elements in the accident sequences.

Common Accident Sequence Elements

Accidents involving erroneous flight instruments share several common elements in the accident sequence. These elements may be viewed as either the chronological progression of events, the active failures that occurred, or the layers of defense in Reason's model of accident causation. The common elements are listed here and described in more detail below.

Fault Occurs
Erroneous Information Displayed

Crew Recognition of Erroneous Information

Crew Response to Erroneous Information

Fault Occurs

Each accident sequence begins with the occurrence of a fault. The fault may take many forms, including a loose screw, broken wire, or incomplete maintenance procedure. During the ensuing investigation, there will be an examination of the latent failures or contributing factors that preceded the fault. For example, the policy of scheduling maintenance personnel for 18-hour shifts may be pertinent in understanding why a particular procedure was omitted. However, for our purposes, the "fault" is the first active failure in the accident sequence.

Erroneous Information Displayed

Ideally, the airplane's flight instrument system will be designed so that correct information is displayed to the crew, even in the event of multiple faults. However, that goal is not always possible. During the investigation of an accident or incident, an engineering evaluation of the instrument system will reveal how and why the presence of the fault affected the information displayed to the crew.

Crew Recognition of Erroneous Information

The next element in the sequence is crew recognition of the erroneous information. As demonstrated by the short duration of both the Comet and 747 flights, loss of accurate attitude information can rapidly lead to loss of control. In contrast, when erroneous airspeed and/or altitude information is displayed, the crew often realizes that something is wrong well before a loss of control occurs. For our purposes, the crew recognition element consists only of the realization that something is amiss, and does not require that the crew accurately diagnose the problem.

Crew Response to Erroneous Information

The last element in the sequence is the most important. Ultimately, it is the crew's response to the erroneous information that will determine the outcome of the flight. As stated by the Honorable Justice M. N. Chandurkar of the High Court of Bombay regarding a Boeing 747-200 that crashed in January 1978, "Malfunction of an ADI is not an emergency and by itself could not have caused the accident."() It is clear that an examination of aircraft accidents involving erroneous instruments must involve not only the instruments themselves, but also the response of the crew.

Case Studies

Having defined the common accident sequence elements, two examples are provided to demonstrate how the accident sequences can be mapped to the common elements mentioned above.

De Havilland Comet 4B - Ankara, Turkey - December 21, 1961

Referring to the 1961 accident, it was found that a screw had come loose in the captain's director horizon. This is the fault that occurred. The screw head eventually obstructed the pitch pointer and prevented it from displaying a pitch attitude greater than 7.5° nose up. "It is believed probable that the captain looked at this instrument for attitude information immediately after unstick and seeing the pitch pointer only about half way to the normal nose-up position on the pitch scale, applied more elevator. Although this would have at once steepened his climb, there would have been no indication of it from the pitch pointer."(1) Thus erroneous information was displayed to the crew. In this accident, it isn't possible to determine if the crew recognized that erroneous information was being displayed. Even if they had realized which of the two director horizons was in error, it is unlikely they would have had time to respond in the 8 to 10 seconds between liftoff and stall. In summary, Table 1 contains the common elements in this accident sequence.

Common Element	Comet 4B Accident in Turkey - 1961
Fault Occurs	A screw came loose in the captain's director horizon
Erroneous Information Displayed	The screw head obstructed the movement of the pitch pointer, preventing it from displaying pitch attitudes greater than 7.5° nose up
Crew Recognition of Erroneous Information	Unknown - but not in time to prevent the subsequent stall
Crew Response to Erroneous Information	Unknown - the stall at such a low altitude made recovery impossible

Table 1 - Common elements in the crash of the De Havilland Comet 4B at Ankara, Turkey on December 21, 1961

Boeing 757-200 - Puerto Plata, Dominican Republic - February 6, 1996

On February 6, 1996 a Boeing 757-200 departed from Puerto Plata, Dominican Republic for a flight to Frankfurt, Germany. During the takeoff roll, the captain noted that his airspeed indicator was not working and asked the first officer to call out airspeeds. However, as the airplane began to climb, the captain said that his airspeed indicator had begun to operate. Later, the captain and first officer noted different airspeeds on their instruments. Three minutes into the flight, an overspeed warning sounded as the airplane climbed through 6,688 feet. Twenty-four seconds later, the stick shaker activated, pitch attitude increased to 21° and the airplane began to descend. Just over one minute later, the airplane was pitched 34° nose down and banked 34° to the left when it struck the ocean and was destroyed. There were no survivors.()

The FDR and CVR were recovered from a depth of 7,200 feet. The recorded values of calibrated airspeed did not correlate with other recorded flight parameters, but instead correlated to a total block of the captain's pitot probe. Because the wreckage was not recovered, the cause of the pitot system obstruction was not determined. However, the probable source of the obstruction was mud and/or debris from a small insect that was introduced in the pitot probe while the airplane was on the ground for the 20 days preceding the crash. This blockage was the fault that occurred.

The blockage trapped air at sea level pressure in the captain's pitot probe. During the takeoff roll, the sensed pitot pressure remained equal to the static pressure resulting in the zero airspeed reading noted by the captain. When the aircraft began to climb after takeoff, outside static pressure began to decrease, but the sensed pitot pressure remained constant. This pressure difference caused the captain's airspeed indicator to begin to move. However, the displayed airspeed value was not related to the airspeed, but was instead related to the airplane's altitude. In this way, erroneous information was displayed to the crew.

During the takeoff roll, the CVR recorded the comment "My airspeed indicator's not working".(5) Thus, the flight crew immediately recognized that erroneous information was being displayed. However, they did not consistently discount the erroneous information for the remainder of the flight.

As the airplane continued to climb, the captain's indicated airspeed continued to increase, eventually triggering an overspeed warning. The crew's response to the erroneous airspeed and overspeed warning was to increase pitch and reduce power. Eventually, the stick shaker activated, the airplane entered a stall and did not recover before impact with the ocean. Table 2 summarizes the common elements in this accident sequence.

Common Element	**757 Accident in Dominican Republic - 1996**
Fault Occurs	An obstruction blocks the captain's pitot probe
Erroneous Information Displayed	Airspeed was calculated from the ambient field elevation pressure trapped in the pitot probe
Crew Recognition of Erroneous Information	The crew identified that erroneous information was displayed during the takeoff roll
Crew Response to Erroneous Information	The crew's response was marked by uncertainty and confusion when faced with erroneous airspeed and overspeed warnings.

Table 2 - Common elements in the crash of the Boeing 757 near Puerto Plata, Dominican Republic, on February 6, 1996

Evolution of Air Data and Attitude Instrument Systems

Having now established the common accident sequence elements, let us now examine how advances in instrument design and operational procedures relate to these elements. But first, let us review the instrument systems from the Comet era and a recently designed successor, the 777.

Pre-1967 (707 Era)

Only captain's and first officer's primary flight instruments, but no standby instruments, are installed on early Boeing commercial airplanes (See Figure 1). The two artificial horizons (attitude indicators) are powered by analog signals from remotely located vertical gyros. Both gyros are lost if all the main airplane generators fail. Because of this, a third, panel-mounted gyro instrument is installed in the center of the instrument panel on later models. The third gyro is AC-powered by a static inverter that receives its DC power from the main airplane battery.

The airspeed indicators and altimeters directly receive pitot and static pressure information from left and right pitot probes and static pressure from two pairs of flush-mounted static ports. These indicators require electrical power for lighting only.()

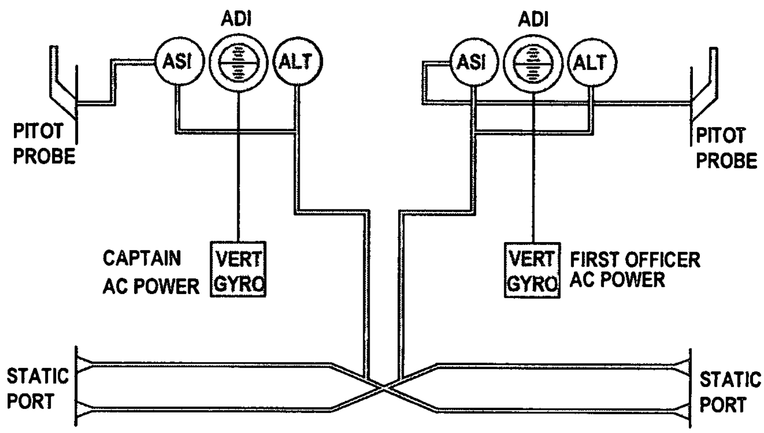


Figure 1 - Pre 1967 (707 Era) Flight Instrument System

<u>*1994 to present (777 Era)*</u>
The primary source for attitude, airspeed, and altitude is the air data inertial reference unit (ADIRU) (See Figure 2). The attitude and air data signals are formatted for display by the airplane information management system (AIMS). The ADIRU design differs from the traditional left-right system partitioning. The ADIRU is a single, fault-tolerant, high-integrity data source for both the captain's and first officer's primary flight displays (PFD). The ADIRU uses multiple redundant inertial sensors for computing attitude and also selects a best altitude and airspeed from three pitot and static pressure sources. As a result, it provides a single set of data for both the captain and first officer, eliminating cross-panel splits.

The pitot and static pressures are measured by small air data modules (ADM) located as close as possible to the respective pressure sources. The ADMs transmit their pressures to the ADIRU through data buses. In the highly improbable event that the ADIRU totally fails, a secondary attitude air data reference unit (SAARU) provides comparable attitude and air data to both PFDs. The SAARU also supplies standby attitude directly to an electronic standby horizon instrument. The standby airspeed indicator and altimeter, both electronic, receive pitot and static pressure from the standby ADMs. This design ensures that displayed data are immune to any first and most second failures of their respective sensors or pressure probes.(6)

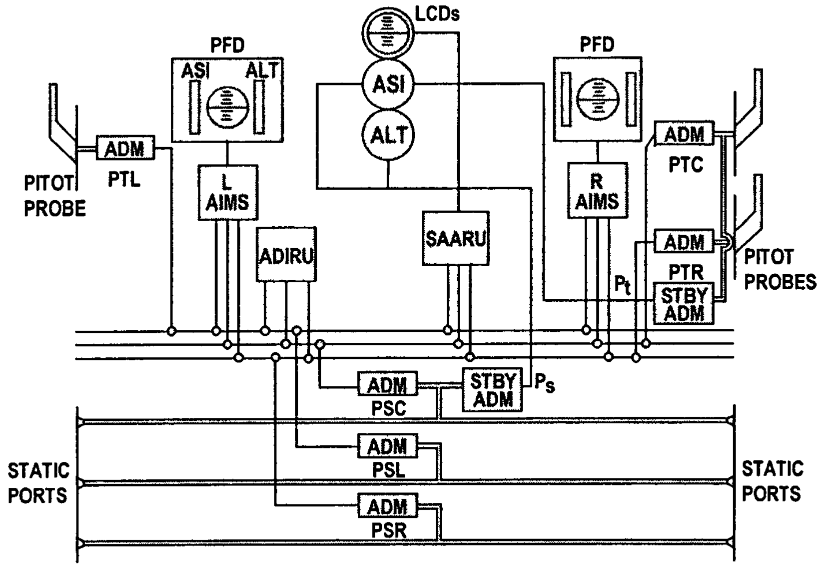


Figure 2 - Post 1994 (777 Era) Flight Instrument System

Flight Instrument Design Differences

As shown above, the past four decades have seen considerable advances in technology and in flight instrument systems. These changes as well as advances in crew procedures can be viewed as fortifications to the defenses against an accident, or as "filling in the holes in the Swiss cheese." That is to say, each one of the changes can be allocated to one or more of the common accident sequence elements described earlier. Table 3 provides a summary of these changes grouped by the common element they affect.

Fault Occurs Automatic operation of pitot and static de-icing systems Mechanical gyros replaced by ring laser gyros Mechanical displays replaced by glass cockpit Elimination of long tubing runs and water traps	Erroneous Information is Displayed Independent left/center/right architecture replaced by integrated, voted solution
Crew Recognition Installation of third independent system EICAS message and aural warnings for attitude disagree EICAS messages and aural warnings for airspeed and altitude disagree Ground proximity warning systems	Crew Response Crew resource management Procedures and checklists Ability to select an alternate air data or attitude source Switching of overspeed warning source with Air Data Source switch Angle-of-attack display Enhanced ground proximity warning systems

Table 3 - Advancds to flight instrument systems and crew procedures address common accident sequence elements involving erroneous instruments.

Advances that reduce the occurrence of faults

Going back to the root cause, it would be desirable to eliminate all faults that could lead to the display of erroneous information. Advances in technology have dramatically increased the reliability of instrument systems and eliminated many of the failure modes of earlier systems. These advances include:

- automatic operation of pitot and static de-icing systems,
- the development of ring laser gyros to replace mechanical gyros,
- the development of flat panel displays to replace mechanical gauges,
- and the use of ADMs to eliminate long tubing runs and water traps.

Regardless of how much progress is made in this area, we can not trust that all faults will be eliminated. Therefore, the faults must be accommodated.

Advances that prevent the display of erroneous information

Perhaps the most significant advance is the concept of automatically displaying the best altitude, airspeed, and attitude information available from multiple sources. The development of the glass cockpit and improvements in computer technology allow the ADIRU on the 777 to monitor the three separate pitot and static sources and "vote out" an erroneous pressure reading. The same strategy is used for attitude data derived from multiple inertial sensors. Consequently, the failure of any one sensor (such as blockage of a pitot tube or static port) does not affect the accuracy of the information displayed to the flight crew. Indeed, most combinations of two failures will not affect the accuracy of the information displayed to the crew. With this important advance, many faults that have in the past led to accidents are now reduced to maintenance items.

Given sufficient simultaneous faults, it is not possible to reliably determine what information is correct and what is erroneous. In that unlikely case, the caution message NAV AIR DATA SYS will appear and each of the three sets of instruments in the flight deck (captain's, first officer's, and standby) will display data from its own independent pressure sources.

Advances that assist crew recognition

Several advances have been made to assist the crew in identifying erroneous information. The first and most basic advance is the addition of standby instruments that provide a third independent source of data. This allows the crew to identify an erroneous system by comparison to the other two systems. Another advance is the increased sophistication of comparators that warn the crew of differences between the captain's and first officer's instruments. Early systems included warning lights near the affected instruments. Current generation airplanes feature EICAS messages, master caution lights, and aural warnings to alert the crew to cross-panel splits. The crew can compare their own instruments against the independent standby instruments to determine which information is valid and which is not.

Ground proximity warning systems (GPWS) were originally developed to alert crews to impending collisions with terrain. Experience has shown that GPWS warnings have served to alert crews to erroneous flight instrument information. Basic GPWS installations use radio altitude to determine terrain closure rates. Therefore, GPWS warnings are reliable, even in the presence of air data system faults. In addition to assisting the crew with recognition of the fault, GPWS will continue to assist the crew during their response.

Advances that assist the crew response

The advances in this area fall into two categories: crew training/procedures and airplane design elements. In the area of training/procedures, the most significant advance is the development of the Crew Resource Management (CRM) training philosophy and related programs. CRM is a highly effective training concept that prepares the crew to effectively deal with any emergent situation, including erroneous information on flight instruments. The benefits of CRM cannot be overstated and are too numerous to discuss here.

In the presence of erroneous information, the following basic actions are paramount to safely completing the flight:

- Recognizing an unusual or suspect indication.
- Keeping control of the airplane with basic piloting skills.
- Taking inventory of reliable information.
- Finding or maintaining favorable flying conditions.
- Getting assistance from others.
- Using checklists.

Current Boeing operations manuals contain an "Airspeed Unreliable" checklist. This procedure provides the crew with appropriate pitch attitude and engine power settings for various phases of flight and various airplane weights. Using the information provided in the procedures, it is possible to conduct a safe landing in the complete absence of valid air data information.

Airplane design features that can affect the crew's response are independent sensing systems and the refinement of crew warning systems. Independent sensing systems are those systems that help the crew maintain control and navigate without reference to erroneous instruments. Examples of these systems include angle-of-attack display, radio altimeters and enhanced ground proximity warning systems (EGPWS). Angle-of-attack can be used as a backup to unreliable airspeed because the calculation of AOA is not greatly affected by pitot or static pressure inputs.() Radio altimeters provide an independent measurement of height above the ground. EGPWS compares the airplanes altitude and position to a internal terrain database to provide additional "look-ahead" terrain warnings. Current implementations of the EGPWS use the concept of a "geometric altitude" derived from Global Positioning System and other sources that allow continued operation in the event of air data system faults.()

When faults occur in the air data system, it is possible for the crew to experience simultaneous overspeed and stall warnings. When an overspeed warning is based on erroneous information, the continuous aural tone that accompanies the warning can make it difficult for the crew to discount the erroneous information and concentrate on valid indications. Current Boeing overspeed warnings are based on the crew's selected air data source. Therefore, once the crew recognizes an erroneous source and selects an alternate valid source, the erroneous warning will cease. Some Boeing models also include procedures for the crew to silence an overspeed warning determined to be erroneous, although this option is not available on JAA certified airplanes. This is an example of an area where FAA and JAA regulations have yet to be harmonized.

Taken together, these advances in aircraft design and operation address the common accident sequence elements identified above. Each layer of defense against an accident has been strengthened.

Success Stories

It is easy to concentrate on major accidents that receive extensive media coverage and wide public interest. However, numerous incidents indicate that the advances mentioned above can prevent accidents.

One such success story is the next to last flight of the 747-200F mentioned above that crashed in 1999.

"As the commander made the right turn after takeoff, the ADI 'Comparator' warning triggered; his recollection was that the buzzer sounded, the 'ATT' flag appeared on his ADI, the Instrument 'WARN' flashing red and the 'ATT' steady amber lights illuminated. When the warning activated, the commander looked at both the standby horizon and the first officer's ADI and realised that his own ADI indication was in error. He instructed the first officer to take control. Once he had done so, the commander selected the ATTITUDE/COMP STAB switch to ALT. After approximately 5 seconds, the ADI indicated correctly and the warnings disappeared."(2)

It is instructive to note that above event occurred in daylight visual meteorological conditions. This is one of the historic keys to success in situations caused by erroneous flight information. No accidents involving unreliable airspeed on large commercial airplanes have occurred when their crews managed to find or remain in daylight visual conditions.

DC-9-32 - May 1998

In May 1998, a DC-9-32 encountered severe hail while climbing through FL200 after departure from Atlanta bound for Chicago. The hail lasted 5 seconds and was accompanied by moderate turbulence that lasted 30 seconds. The three front windscreen outer panes shattered and the radome separated from the airplane. The captain's and first officer's airspeed indicators became inoperative and it became very noisy in the cockpit. They declared an emergency and asked for directions to the nearest airport. An approach and uneventful landing was made with air traffic controllers reporting the airplane's groundspeed every 10-15 seconds.()

These examples demonstrate that flights may be safely completed in the presence of erroneous flight instrument information. Our goal is to have all such flights completed safely.

Summary

Erroneous instruments have led to a number of catastrophic accidents. Although each of the accidents is unique, an examination of the accident sequences reveals four common elements: the fault occurs, erroneous information is displayed, the crew recognizes the error and the crew responds to the resulting situation. These elements may also be considered as the layers of defense against an accident. Advances in aircraft system design and operational procedures have strengthened each layer of defense. Several events have demonstrated that these defenses can prevent aircraft accidents. However, we cannot rest on our laurels. The enhancement of safety is a never-ending task.

附錄十八

航空器失事生還因素之改善情形

FEDERAL AVIATION ADMINISTRATION 20 YEARS OF CRASHWORTHINESS IMPROVEMENTS

John J. Petrakis
Federal Aviation Administration

FEDERAL AVIATION ADMINISTRATION 20 YEARS OF CRASHWORTHINESS IMPROVEMENTS

John J. Petrakis
Federal Aviation Administration
800 Independence Ave. SW
Washington, DC 20591

Safety improvements, in general, afford a true assessment of the resolve of an organization to exact incremental increases in the level of safety provided. This is well illustrated by the aviation safety community's ability to readily identify (through accident investigation) and correct (through regulatory change) safety issues. As a measure the effectiveness of the FAA's crashworthiness program, you only need to look at the twenty years of accomplishments presented in this paper. The level of commitment to safety by the aviation safety community has yielded some remarkable crashworthiness improvements and some are still pending.

Crashworthiness, while being a relatively new discipline, has matured significantly relative to its technical advancements. The terms "crashworthiness", "cabin safety" and "survivability" represent broadly related safety issues and are used interchangeably.

In the context of this paper, crashworthiness includes three basic cabin safety components, which interrelate to provide the essentials of occupant protection in an emergency. These components are "Occupant Impact Protection," "Fire Safety," and " Emergency Evacuation."

The ultimate goal of occupant impact protection is to provide injury prevention/reduction by creating a survivable environment through structural crashworthiness, occupant restraint and human injury criteria.

Fire safety must maintain or increase the time available for emergency egress. This predominantly involves reducing the severity of post crash fires and the flammability of interior materials. Included within fire safety is equipment designed to mitigate the effects of foreseeable situations; such as, floor proximity lighting or protective breathing equipment.

Areas associated with emergency evacuation, which entails improving the rate of egress, include the basic airplane interior arrangement, escape system and survival equipment design and crew performance and training.

These three crashworthiness components are most effective when dealt with as a system. Occupant protection improvements are diminished, if the cabin interior materials have poor flammability characteristics, and the advantages of highly fire resistant materials are compromised by inadequate escape system design. Each component must take advantage of the advances made in the other areas.

REGULATORY BACKGROUND

The airworthiness requirements of Title 14 of the Code of Federal Regulations (14 CFR) part 25 for transport category airplanes were issued November 3, 1964. The very first amendment 25-1 was issued four months later and was predominantly a cabin safety revision. This revision added basic passenger emergency evacuation procedures and equipment requirements to part 25. Over the intervening 37 years, there were 32 crashworthiness amendments (14 airworthiness and 18 operational) affecting transport category airplanes. All of these crashworthiness amendments were incorporated into the rules within the last twenty years (See Tables 1-3).

Some safety professionals maintain that the primary goal of any aviation safety program must be to mitigate accidents. They do not believe it is advantageous to expend valuable time and resources on cabin safety, at all. The fact that the commercial airplane hull loss accident rate (accidents per million departures) has remained relatively constant over the last 15 years seems to be indicative of the relative success of the aviation community in preventing accidents. The hull loss accident rate has been reduced to a very low 1.2 per million departures during a period of steadily increasing air traffic. If the accident rate were reduced to zero, clearly there would be no need for improving the "crashworthiness" of airplanes. So, in the face of accident prevention improvements, it appears that at least for the foreseeable future, accidents will continue to occur.

Over the past 20 years, the FAA has developed numerous regulations, Advisory Circulars (AC), and Technical Standard Orders (TSO) that have improved occupant protection and increased cabin safety. In addition to the 32 crashworthiness amendments mentioned above, there are 5 pending notice of proposed rulemaking (NPRM). Nineteen associated AC's and 10 TSO's also were issued (See Tables 1-3). In addition, 3 amendments to part 23 for commuter category airplanes were issued. Not to mention, the numerous research and development projects and draft documents that are currently under consideration.

The summary that follows addresses all of the aforementioned rulemaking and related activities completed or proposed over the past 20 years with regard to the crashworthiness of airplanes used in commercial operation. These activities cover impact protection, fire safety, water survival, and emergency evacuation equipment, systems, and procedures. Other relevant occupant safety issues also are included in this document. Some of these activities addressed recommendations made during the 1984 Cabin Safety Conference and Workshop, as well as those made during the 1985 Evacuation Task Force Public Technical Conference.

In the area of occupant protection, the long standing requirements were based on static strength of the seat, restraint system, and their attachments and the geometric relationship of the seat to its interior surroundings. To more accurately reflect the loading conditions of a real accident, in 1986, dynamic seat testing requirements were adopted. The new requirements included a quantitative assessment of human injury criteria. These requirements blended the inherent structural capability of the airplane, and human tolerance limits to arrive at a set of complementary criteria. These dynamic tests have necessitated a fresh approach to seat design. In fact, benefits of dynamically testing seats have already been revealed in accidents. While no two accidents are the same, there have been accidents of comparable severity, with and without seats designed to the dynamic seat standards and occupant survivability was much greater in the airplane equipped with improved seats.

The most activity has occurred in the area of fire safety where the initial flammability requirements were very rudimentary. The single most effective cabin safety improvement was the implementation of seat cushion "fire-blocking" in 1984. The efforts of FAA, NASA, NTSB and industry yielded seat cushions that were vastly improved to resist the effects of fire. Seat cushion foams were the major contributors to the severity and rapid spread of a cabin fire. The development of highly fire resistant materials to encapsulate the foam significantly extended the time available for egress. These fire-blocking layers immediately impacted the overall level of safety in accidents involving fire.

The vast majority of cabin interior materials are in the cabin surface areas, i.e. sidewalls, ceilings, stowage compartments etc. These materials also contributed to the severity and growth of a post-crash fire. Laboratory material fire test methods were developed by correlation with the full-scale fire test performance of materials to enable manufacturers to identify the more desirable materials. The test methods involved measuring the amount of heat and amount of smoke given off by a material, when exposed to a radiant heat source. These requirements effectively pushed the state of the art for aircraft interior materials.

More recent requirements have addressed improvements in cargo compartment liners and escape slides. A realistic performance test was mandated to determine a liner's resistance to severe fire penetration and escape slide materials were upgraded to resist the radiant heat of a post crash fire.

In each of these cases, the requirements were written for the specific application of the materials, and measured the most significant performance characteristics with regard to safety.

Other requirements related to improving emergency evacuation have also evolved over the years. Access to exits has been continuously improved. For the first time, there are now specific passageway dimensions for Type III emergency exits. Escape slides have evolved to be capable of much higher passenger flow rates. An increase in the time available for egress has come with improved technology emergency escape slides. The current state of the art allows automatic preparation of the escape slide on exit opening in about 2 seconds on a narrow body airplane, and about 6 seconds on a wide body airplane. These were huge improvements compared to the '60's and leave little room for improvement. In general, the ratio of passengers to exit capacity has decreased, so that there is more evacuation capability for a given number of passengers.

Most of the aforementioned requirements have approached the state of the art in technology. At this point, any meaningful improvement in occupant protection would probably require some basic change to the airframe structure. For example, 20G seats would be useless if they could not remain attached to the airframe and would not add to safety. Changes to the cabin interior arrangement, that would improve egress rate, would probably reduce passenger seating capacity; either as a direct measure to increase the ratio of exits to passengers, or as a result of providing additional space elsewhere. In any case, it isn't clear just what these changes would be, or what effect would be expected.

Most of the airworthiness changes described below were supported by research and development performed at the FAA Technical Center (FAATC) or the FAA Civil Aerospace Medical Institute (CAMI) and represent the culmination of years of research and development. Ongoing crashworthiness research, under a Cabin Safety Research Plan, continues to integrate the areas discussed in this summary and directly supports NPRMs, ACs and TSOs.

The following presents a synopsis of 20 years of crashworthiness improvements developed and implemented by the FAA. All of the improvements are tabulated in Tables 1-3. Some of the most significant changes are discussed in the following sections.

While not always acknowledged, it is important to note that accident investigations were fundamental in the evolution of many of these improvements. Many crashworthiness improvements have directly or indirectly resulted from accident investigation safety recommendations.

OCCUPANT IMPACT PROTECTION

Flight Attendant Seat and Shoulder Harnesses: Improved standards for flight attendant upper torso support, shoulder harnesses with a single-point release, and improved galley restraint requirements have been in effect since March 1982. In December 1981, AC 25.785-1 was issued and described flight attendant seat requirements and identified an acceptable means of compliance with that rule. In January 1994, a revised AC was issued which offered guidance on flight attendant seat head strike safe zones and restraint system installations. Flight attendant direct view was removed from this AC, pending a recommendation from a harmonization working group. A draft revision of AC 25.785-1A will be issued for public comment pending FAA acceptance of recommendations from the harmonization working group.

Shoulder Harness Restraint Systems: At the request of the FAA, an ad hoc committee of the Society of Automotive Engineers (SAE) developed criteria for torso restraint systems intended for use in rotorcraft and general aviation airplanes. On March 27, 1987, TSO-Cll4 was issued which adopted SAE Aerospace Standard (AS) 8043 and which specified the performance criteria for torso restraint systems intended for use in any application. This TSO requires single-buckle release, fatigue testing of buckle latches, automatic locking retractors, and emergency locking retractors. It should also be noted that TSO-C22g was updated using AS 8043 on March 5, 1993.

Human Tolerance to Impact: On June 20, 1985, AC 21-22 was issued, which described a range of impact trauma that is considered to be reasonable human injury criteria for use in the evaluation of occupant survivability characteristics. Some of the human tolerance values specified in the AC were used in rule changes to transport, rotorcraft, and general aviation airworthiness requirements as pass/fail criteria for dynamically tested occupant seats.

Seat Standards: Improved seat standards were developed for transport and commuter category aircraft in the late 1980s. These dynamic test and impact injury criteria represented typical survivable accidents. The test criteria were unique to each aircraft category due to distinct crash impact scenarios and unique structural design characteristics.

Improved transport seat safety standards became effective on June 16, 1988. These standards upgraded occupant protection during emergency landing conditions by requiring 16g dynamic crash impact criteria for occupant seat/restraint systems. Static design load factors for seats and items of mass also were increased and specific head, chest, spine and leg impact injury criteria were added to assess occupant survival. The rule also specified that seats and attachments, safety belts, and shoulder harnesses may not impede an evacuation after a minor crash.

Compliance information and guidance applicable to dynamic testing of seats on transport category airplanes is contained in AC 25.562-1, which was issued in March 1990, and revised in January 1996. This AC outlines test procedures, test facility evaluation considerations, and basic factors for determining acceptability of tests.

Aircraft Seating Systems: The SAE was asked by the FAA to create a new AS for dynamic testing of seats. As a result, AS 8049 was developed and is referenced in TSO-C127, which was issued on March 30, 1992 and was revised on August 21, 1998. This TSO created the minimum performance standards for an entire seating system for each aircraft category. Due to the uniqueness of the dynamic response requirements of each category of aircraft and the response of a particular aircraft/seating system combination, TSO-C127 seating systems do not offer the same flexibility that existed under TSO-C39.

Seat Retrofit: On May 11, 1988, NPRM 88-8 proposed to modify air carrier and scheduled air taxi operating rules to require the retrofit of in service transport category airplanes with improved 16g dynamic seats. This proposal would require that all passenger and flight attendant seats on transport category airplanes certificated after January 1, 1958, and used in certain operations comply with the improved crashworthiness standards in effect on June 16, 1988.

This pending NPRM proposed a complete fleet retrofit with improved 16g dynamic seats. Three public meetings were held in conjunction with the development of a proposed final rule. The last meeting was held in December 1998 at which time a proposed final rule was unveiled. The proposed final rule presented would require the retrofit of all passenger and flight attendant seats on transport category airplanes with 16g dynamic seats 4 years after the effective date of the final rule with the exception of "16g compatible" seats. In addition, newly manufactured transport category airplanes would be required to use improved 16g dynamic seats.

A variation of the above proposal will be presented for public comment soon, as a Supplemental Notice of Proposed Rulemaking (SNPRM) will be issued later this year. One of the proposals under consideration would still require newly manufactured part 121 airplanes to be equipped with full 16g dynamic seats 4 years after effective date of rule. However, seat replacement on existing part 121 airplanes would not be mandatory. Only when an airline elected to replace any of the seats on an airplane would they be required to replace ALL of the seats in that class within that airplane with full 16g dynamic seats. Within fourteen years, all transport category airplanes must be equipped with 16g dynamic seats. In addition, the FAA would seek public comment on the seat replacement practices of a wide variety of 121 operators.

Revised Seat Standards: An NPRM is being developed to amend the seat dynamic test requirements for transport category airplanes to relieve the requirement to test crew seats in the cockpit with floor warpage, and to require that seat leg reaction loads be recorded during the dynamic tests. This proposed change is necessary to accommodate the unique design features of crew seats when testing to the new dynamic emergency landing conditions. The seat leg reaction loads developed during the dynamic tests are necessary to ensure adequate floor strength to support the seat loads. This is being harmonized with the Joint Aviation Authorities (JAA).

Transport Airplane Interiors Crashworthiness Handbook, AC 25-17: This handbook is a comprehensive document that consolidates previously issued policy and guidance material regarding crashworthiness requirements of transport category airplanes. Major areas of consideration addressed in the AC include protecting occupants during crash impacts, providing for rapid occupant evacuations, and minimizing the development and severity of post crash fires. AC 25-17 was issued in July 1991 and has been widely distributed to industry as a reference. This AC is in the process of being revised.

Child Restraint Systems (CRS):
The FAA is developing a NPRM to propose the mandatory use of CRS in air carrier operations. Under consideration is a proposal that would eliminate the longstanding ability afforded parents to carry their children on their laps at no cost. Instead, children under the age of two, specifically children under 40 lb., would be required to be in an approved CRS during takeoff, landing and movement on the surface. Airlines would be required to establish a CRS program with procedures to provide a CRS if a passenger shows up at the gate without a CRS, with an unapproved CRS, or with a CRS that does not properly fit in the passenger seat.

At the present time, an approved CRS is one that has Federal Motor Vehicle Safety Standard (FMVSS) 213 approval. An FMVSS 213 approval indicates that a CRS has met automotive and an optional limited aviation standards.

The proposal being evaluated would allow the use of existing FMVSS 213 approved CRS for use on air carriers for a limited time. After a specified date, CRS approved for use in air carrier operations would have to meet an improved Aviation Standard No. 213 . The introduction of an enhanced aviation CRS standard would not impose a change to the automotive standard but would allow the dual certification of CRS for use in both modes of transportation or would permit the use of an "aircraft-only" CRS.

In the interim, TSO-C100b, which was made available for public comment on August 7, 2001, will be issued to allow those CRS manufacturers the alternative to produce an approved aircraft-only CRS. This TSO will establish a minimum performance standard designed specifically to demonstrate the capability of CRS to properly protect the occupant in an aviation environment.

Design of Aircraft Interiors for Security: On 27 October 1999, ARAC was tasked to undertake the implementation of new international rules on the design of airplanes from a security perspective. Searches are currently required under certain conditions by ICAO standards. A harmonization working group has been formed to evaluate designing aircraft interiors to facilitate searches. The two main objectives are to make it increasingly difficult to hide hazardous materials and to improve the effectiveness of searches. Up to now, the need to search has not been a consideration in the design of the interior. Consequently, there are areas that could be improved from a security standpoint. The rulemaking under development would require that certain considerations be made at the design phase to facilitate searching.

Transport category airplanes contain many areas that are not readily visible, but are accessible with relative ease. For example, under seat areas, arm rest tray storage areas, video cavities, IFE boxes, Telephone cavities and seat back pockets are all easily accessed, but not readily visible. In addition, lavatories are generally highly accessible but, by their very nature, out of sight of other passengers or crew.

There are two potential approaches to rapid searching. The first approach would reduce the number of areas to hide a device. This might be done by providing locks or use of special tools to access certain areas, or, by eliminating certain areas. The second approach would improve the ease with which certain areas can be searched by using design features that allow a faster and easier search to be carried out, e.g.. using transparent panels or mirrors that make more of a compartment visible.

FIRE SAFETY

Seat Cushion Fire Blocking: On October 26, 1984, new standards were published which significantly reduced the flammability of foam seat cushions. These standards specified a burn test methodology that was more representative of a high-intensity, post-crash fuel fire. Seat cushions that pass the test were demonstrated to delay the onset of flashover within the cabin and to reduce the spread of flame and products of combustion such that evacuation times were extended by at least 40 seconds in a post-crash fire. These seat cushions also significantly reduced the spread of in-flight fires. The rule required that all transport category airplanes type certificated after January 1, 1958, and used in air carrier and air taxi operations must be in compliance with the new standards by November 26, 1987.

Guidance concerning compliance with the seat cushion flammability requirements are contained in AC 25.853-1, which was issued in September 1986. In particular, criteria for handling "similar" dress cover materials were provided. A similar requirement has been proposed for commuter category airplanes.

Special Federal Aviation Regulation (SFAR) 52 was issued on November 25, 1987, to address an ambiguity in the regulation, which incorporated by reference these standards into part 135. This SFAR allowed affected part 135 operators of certain large airplanes additional time to comply with the aforementioned seat cushion fire blocking requirements. SFAR 52 terminated on December 1, 1988.

As revised, TSO-C39b and TSO-C72c issued on April 17, 1987, and February 19, 1987, respectively, provide for the correct marking of seats and seat cushions that incorporate fire blocking material. Manufacturers are allowed the option of conducting the required airworthiness fire blocking burn testing, after which, seat cushions could be marked to show compliance with the fire blocking requirements of 14 CFR 25.853(c).

Smoke Detectors and Fire Extinguishers: On March 29, 1985, operating standards were published to require air carriers to: (1) equip each lavatory with a smoke detector system; (2) equip each lavatory trash receptacle with a built-in automatic fire extinguisher; and (3) have at least two of the required cabin fire extinguishers contain Halon 1211 (or an equivalent) as the extinguishing agent. Compliance with these regulations was required by October 29, 1986; April

29, 1987; and April 29, 1985; respectively. In addition, installation of Class E cargo compartment fire extinguishers was required as of October 29, 1985. Subsequently, these standards were incorporated into the airworthiness standards of part 25, effective May 1991.

Cargo Compartment Liners: On May 16, 1986, standards to improve fire safety in Class C and Class D category cargo and baggage compartments were issued. These standards became effective on June 16, 1986 and established a burn-through resistance fire test criteria for Class C and Class D compartment ceiling and wall liners. The required fire test method subjects these liners to the maximum fire conditions measured during the full-scale tests and permits no flame penetration and minimal flaming of the specimen. The standards also limit the volume of Class D compartments to 1,000 cubic feet. Similar requirements are being proposed for commuter category airplanes. Operating rules for transport category airplanes used in air carrier, air taxi, or commercial service that were certificated after January 1, 1958, also were modified to require installation of improved cargo liners that meet the above burn-through criteria or that are constructed of rigid fiberglass or aluminum. Compliance was required by March 1991. Several exemptions were granted due lack of parts availability or lack of recognition on the part of manufacturers regarding the status of their airplanes.

Crewmember Protective Breathing Equipment (PBE): To establish criteria for PBE used by air transport flight crewmembers, TSO-C99 was issued in June 1983. Following the issuance of TSO-C99, a number of approved devices were tested and were found to permit contaminant concentration levels beyond those specified.

Generally, PBE equipment is used by sedentary flight crewmembers. However, PBE is approved under part 121 if it is used in a state other than sedentary. Therefore, the FAA revised air carrier operating rules on May 26, 1987, to impose additional PBE requirements for flight attendants, in addition to flight crewmembers, to protect them while fighting on-board fires. The operating rule change, which became effective on July 6, 1987, specified (1) the minimum performance criteria for PBE used to fight in-flight fires; (2) the need to perform an approved fire-fighting drill using hand extinguisher and PBE; (3) the location of PBE in the passenger compartment within three feet of required hand-held fire extinguishers, when possible; and (4) clarification of certain emergency drill requirements. Compliance with this rule was required by July 6, 1989. In support of this rule, improved performance standards for crewmember PBE were developed and were issued under TSO-C116 on March 1, 1990.

Fuselage Burnthrough Protection: Another fire safety improvement under consideration would require that thermal/acoustic insulation be provided to enhance resistance to penetration from an external fuel fire. NPRM 00-09 was issued on September 8, 2000. The proposal will require new flammability test methods and criteria that specifically addresses flame propagation to reduce severity of cabin fires and external post-crash fire fuselage burnthrough. These proposed standards address both newly type certificated airplanes, as well as airplanes that are currently in production. The proposal was based on extensive research conducted by the FAA and other airworthiness regulatory authorities.

Cabin Interior Materials: Improved flammability standards for cabin interiors on transport category airplanes were issued July 10, 1986 and were revised on August 25, 1988. The standards contain test criteria that were based on full-scale tests conducted at the FAATC. Fire testing of interior materials (i.e., sidewalls, ceilings, storage bins, and partitions) was established to improve occupant safety in the cabin environment during post-crash fires.

The airworthiness requirements affect new airplanes as well as older airplanes that are being refurbished. The rule specifies the allowable measured heat release from interior panels (using the Ohio State University (OSU) rate of heat release apparatus). In addition, panels will be required to have a minimum optical smoke density measured (using the National Bureau of Standards (NBS) smoke chamber). These requirements delay the onset of cabin flashover and reduce the level of smoke generated, which, to a great degree, controls occupant survivability during a post-crash fire. A two-step compliance criterion was employed to eliminate the more hazardous materials. Airplanes in which the cabin interior were substantially replaced, as well as newly manufactured airplanes, must meet interim heat release rate standards after August 20, 1988; after August 20, 1990, those airplanes must meet more restrictive heat release rate and smoke density standards.

Passenger Protective Breathing Equipment (PPBE): Following a technical evaluation and the lengthy consideration and careful review of a detailed net safety benefit study, the FAA concluded that PPBE would likely reduce overall passenger safety by delaying evacuation. While the United Kingdom Civil Aviation Authority (UKCAA) has issued a specification for such devices, it is not allowing airlines under its authority to install them due to potential degradation of safety. A similar position has been adopted by the FAA, as stated in policy letter of September 28,1995.

Aircraft Cabin Water Spray System: With significant interest from industry, aircraft cabin water spray systems have had extensive research. However, no regulatory activity has been undertaken. A water spray system is intended to delay fire penetration into the cabin, to minimize combustion of cabin materials, to reduce cabin temperatures to prevent flashover, and to provide some "clean up" of harmful combustion products in the cabin air. The spray provides fire extinguishment/suppression and attenuation of thermal radiation. Research findings indicate that a system capable of operating at low flow rates from small amounts of dedicated water would provide increased survival time. However, based on a projection of historical accident rates, the expected benefits were much less than the expected cost. Follow on work in this area is focused on the ability of water spray to serve other fire protection needs (cargo, cabin, engine) and on a reassessment of the benefit based on risk analysis.

EMERGENCY EVACUATION

Life Preservers: TSO-C13d was issued in January 1983 and contained improved requirements for life preservers used aboard aircraft. Those requirements were revised in TSO-C13e issued on April 23, 1986. The improvements included: a packaged adult life preserver with an unassisted donning time requirement of 25 seconds; creation of an infant category of life preservers with a donning time requirement of 30 seconds on a child or infant by another adult; use of one or more inflation chambers; use of one securing attachment and adjustment for fit; and increased buoyancy and flotation attitude requirements. In addition, TSO-C13e specified that after April 23, 1988, no previously approved TSO-C13 life preserver may be marked as FAA TSO-approved. The FAA rescinded the latter requirement by issuance of TSO-C13f in September 1992. This version of the TSO added specific requirements for infant-small child life preservers: thermal protection; donning and jump testing; anthropometric data for infant-small child life preserver dummy; and additional specifications for components.

Emergency Evacuation Slides, Ramps, and Slide/Raft Combinations: On June 3, 1983, TSO-C69a was issued. These requirements were revised in TSO-C69b, which was issued on August 17, 1988. In general, TSO-C69b specified criteria for hydrolysis resistance porosity tests of the pressure holding materials, specified the puncture strength of the sliding surface, and provided for the use of evacuation slides as flotation platforms. The revised TSO also required that these devices meet the radiant heat resistance criteria. These revisions have significantly improved the ability of these passenger evacuation devices to remain operative in the near presence of fire and, in the case of the evacuation slide, have allowed for its use during a ditching by requiring quick release girts and handholds. In fact, all newly purchased evacuation slides must meet the improved standards and eventually will be used on the current fleet, even though the FAA has not sought a mandatory retrofit. The latest revision, TSO-C69c, has criteria which improves the beam strength of the inflatable and provides for lighting.

Improved Water Survival Equipment: Responding to the Airport and Airway Safety and Capacity Enhancement Act of 1987 and NTSB safety recommendations, the FAA issued an NPRM 88-11 on June 27, 1988, which proposed standards for improved water survival equipment. The operational rule changes proposed to require all air carrier and air taxi operators to provide each occupant, including infants and small children, with an approved flotation seat cushion (TSO-C72c) and a life preserver (TSO-C13) with automatically activated survivor locator lights (TSO-C85). These devices would be required regardless of whether the airplane is used in overwater operation. The proposed rule would require infant and small-child life preservers (TSO-C13f) to be provided within one year and adult life preservers and flotation seat cushions to be provided within three years after the effective date of the final rule. The proposed rule would require the same type of life preserver to be used on each aircraft with same donning procedures, retention and inflation means within one year.

The proposed rule would require evacuation slides (TSO-C69b) at certain main floor level exits to be designed to function as emergency flotation devices with quick-release girts and handholds. Installation of the improved slides would be required within three years.

Finally, it is proposed that, prior to each takeoff, operators be required to provide the appropriate passenger briefing on the location and use of the flotation equipment and a demonstration on donning a life preserver.

This pending rulemaking has undergone some further evaluation and the FAA has decided to issue a SNPRM. The relevance of this proposal has remained strong. The original proposal has one significant change under evaluation along with several compliance date changes. Nevertheless, the substance of most of the original proposal remains unchanged.
The proposal to require both a seat cushion and a life preserver has been reconsidered. Under consideration for all air carrier and air taxi operators is the need to provide EACH occupant with an approved flotation seat cushion, but not a life preserver and to provide infant-small child life preservers. The date required for infant-small child life preservers to be provided will possibly be extended to 18 months.

In addition, the proposal to require evacuation slides at certain main floor level exits to be designed to function as emergency flotation devices with quick-release girts and handholds may be extended to 4 years.

This SNPRM is pending and should be issue later this year.

Survival Equipment in Overwater Operations: AC 120-47, which was issued on June 12, 1987, provides guidance regarding water survival items that should be carried onboard an aircraft during extended overwater operations. As a result of the issuance of SAE AS 5134 for flashing strobe light on June 2001, this AC will be revised and updated to reflect current technology developments in survival equipment.

Emergency Exit Distance: On July 24, 1989, parts 21, 25, and 121 were amended to limit the distance between adjacent exits to no more than 60 feet. These standards are applicable to newly manufactured and in-service transport category airplanes used in air carrier operations.

Type III Exit Access: On June 3, 1992, new transport airworthiness standards were issued which specified the requirements for access to Type III exits. These standards require improved placarding and specific passageways (for airplanes with 60 or more seats) to Type III exits. Results of evacuation tests conducted at CAMI indicated that increased access to exits would improve the ability of occupants to evacuate an airplane during an emergency. Findings from additional testing conducted after issuance of the final rule indicated that the same improvement in evacuation is possible using a smaller passageway. In light of this information, an Aviation Rulemaking Advisory Committee (ARAC) working group was tasked to develop general access to passageway requirements. In the meantime, approvals can be handled by an equivalent level of safety finding.

Uniform Exit Distribution: AC 25.807-1 was issued on August 13, 1990 and provides more definitive information concerning the means of demonstrating compliance with the requirement for passenger and exit configurations to be uniformly distributed, as practical, taking into account passenger distribution.

Type and Number of Emergency Exits: On November 1, 1996, part 25 was amended to provide consistent standards with respect to exit types and quantities, and replaces the existing exit tables. In addition, two new exit types, Type B and Type C, were introduced. This rule change also required a reduction in the maximum inflation time for emergency escape slides.

Evacuation Demonstration: Criteria for conducting emergency evacuation demonstrations, as well as for preparing evacuation analyses, and addressing the conditions under which an analysis or test is appropriate are contained in AC 25.803-1 issued on November 13, 1989. An ARAC working group is currently developing a revision of this AD to address concerns regarding potential injury to participants.

Independent Power Supply for Public Address (PA) System: Effective November 27, 1989, the airworthiness standards and operating rules for air carrier and air taxi operators were revised to ensure the availability of the PA system during an emergency. These changes are intended to facilitate rapid passenger evacuation in an emergency and are applicable to airplanes required to have a PA system and that are manufactured after one year after the effective date of this rule.

Miscellaneous Emergency Evacuation Requirements: On September 27, 1993, part 25 was revised to require accomplishment of procedures for conducting an emergency evacuation demonstration without flight crew involvement, and changed the age/sex distribution for participants. This rule also standardized requirements for emergency exit handle illumination for various exit types and added a requirement for a "push-to-talk" switch for the PA system. The latter requirement prevents inadvertent disabling of the system due to an unstowed microphone.

Floor Proximity Lighting: Airworthiness performance and operational standards for floor proximity emergency escape path marking on transport category airplanes became effective on November 26, 1984. The rule change required installation of an additional independently powered emergency lighting system, which provides evacuation guidance when all illumination is obscured four feet above the aisle floor. By November 26, 1986, all air carrier airplanes type certificated after January 1, 1958, were required to be retrofitted with approved systems.

Guidance on system parameters and on demonstrations conducted with passengers was provided in AC 25.812-1. A clarifying revision, AC 25.812-1A, was issued on May 22, 1989. The AC also provided guidance on the power supply required at critical ambient conditions and lighting required when transverse vertical fuselage separation occurs during a crash landing. Subsequently, AC 25.812-2 was issued on July 24, 1997 to specifically address incorporating photoluminescent elements incorporated into floor proximity escape path lighting.

Miscellaneous Cabin Safety Changes: NPRM 96-9 was issued on July 16, 1996. This proposal would amend part 25 to require an assist handle at all designated flight attendant assist spaces to enable attendants to steady themselves while helping passengers out the exit and to require a means to hold door-type emergency exits open when opening the door in an emergency. The NPRM also proposed to require a viewing window (or equivalent) to enable assessment of outside conditions prior to opening an emergency exit and to require a 12" x 20" area on the floor at each emergency exit for flight attendant assist space. Finally, the proposal would require that oxygen masks be connected to the oxygen supply and would prohibit the installation of an interior door between a passenger and an emergency exit. Several of the proposed changes would be included in part 121 and become retroactive. This final rule is being coordinated within the FAA.

Emergency Evacuation Demonstration: To further refine the requirements for emergency evacuation demonstrations, NPRM 95-9 was issued for the purposes of reducing potential injuries to participants. These proposals resulted from ARAC tasking. In addition, a revision to AC 25.803-1 is currently being developed. The final rule and AC are being coordinated within the FAA.

TABLE 1. OCCUPANT IMPACT PROTECTION

PROJECT/SUBJECT	FAA ACTION ISSUED(COMPLI,
1. USE OF CHILD RESTRAINT SYSTEMS (CRS)	ANPRM 98-2
	2/18/98
2. PEFORMANCE STANDARDS FOR CRS	TSO-C100a
	3/15/85
	SAE AS 5276
11/1/00	
3. USE OF CRS ON TRANSPORT AIRCRAFT	AMEND 121-230, 13:
	9/8/92(10/15/92)
GENERAL CRS USE ON AIRCRAFT	AC 91-62 (-62A DRA:
	2/26/85 & 9/19/97
4 BAN ON BOOSTER SEATS AND HARNESS-	AMEND 121-255 & 1:
	5/24/96(9/3/96)
AND VEST-TYPE CRS	AMEND 91-250
5/24/96(9/3/96)	
5. FLIGHT ATTENDANT SEATS AND	AC 25.785-1A
	1/6/94
SHOULDER HARNESSES (2)	
6. G.A. SHOULDER HARNESSES	AMEND 23-32
	11/6/85(12/12/85)
	AC 21-34
	6/4/93
7. ROTORCRAFT SHOULDER HARNESSES	AMEND 27-25
	11/13/89(12/13/89)
8. TORSO RESTRAINT SYSTEMS	TSO-C114
	3/27/87
9. SAFETY BELTS	TSO-C22g
3/5/93	
10 INJURY CRITERIA FOR	AC
21-22	
	6/20/
85	

HUMAN EXPOSURE TO IMPACT

11. TRANSPORT SEAT DYNAMIC TEST CRITERIA
AMEMD 25-64
512/88(6/16/88)
AC
25.562-1A1/19/96

12. ROTORCRAFT (NORMAL/TRANSPORT)
AMEND 27-25
11/13/89(12/13/89)
SEAT DYNAMIC TEST CRITERIA
AMEND 29-29
3/11/90(4/12/90)
AC
20-137
3/30/92

13. GENERAL AVIATION
AMEND 23-36
8/15/88(9/14/88)
SEAT DYNAMIC TEST CRITERIA (1) *AC*
23.562-1
6/22/89

14. IMPROVED SEAT RETROFIT (TRANSPORT)
NPRM 88-8
5/11/88

15. TRANSPORT, ROTORCRAFT AND G.A. SEATING
TSO-C127(-C127a)
3/30/92(8/21/98)
SYSTEMS PERFORMANCE STANDARD SAE
AS8049A 5/16/97

16 TRANSPORT CRASHWORTHINESS HANDBOOK AC
25-17 7/15/91

17 AIRWORTHINESS REQUIREMENTS FOR NEW
AMEND 23-34
1/8/87
COMMUTER CATEGORY AIRPLANES

(1) 1984 Cabin Safety Conference/Workshop

Recommendatıons

(2) 1985 Emergency Evacuation Task Force

Recommendations

TABLE 2. FIRE SAFETY

PROCJECT/SUBJECT ISSUED(COMPLIANCE)	FAA ACTION
1. EVACUATION SLIDE HEAT RESISTANCE	TSO-C69a
2. FLOOR PROXIMITY LIGHTING (2)	AMEND 25-58 &121-
	AC 25.812-1A
INCORPORATING PHOTOLUMINESCENT ELEMENTS	AC 25 812-2
3. SEAT CUSHION FIRE BLOCKING	AMEND 121-184
	AMEND 25-59 & 29-2
	AC 25.853-1
EXTENSION FOR PART 135	SFAR 52
4. LAVATORY SMOKE DETECTORS &	AMEND 121-185
HALON FIRE EXTINGUISHERS	AMEND 25-74
5. HAND FIRE EXTINGUISHERS FOR USE IN AIRCRAFT	AC 20-42A
6. LAVATORY AUTOMATIC FIRE EXTINGUISHER	AMEND 121-185
	AMEND 25-74
7. CLASS E CARGO COMPARTMENT	AMEND 121-185
FIRE EXTINGUISHERS	AMEND 25-74

8. CLASS C & D CARGO OR BAGGAGE COMPARTMENTS

AMEND 25-60

5/16/86(6/16/86)

9. IMPROVED CARGO LINERS

AMEND 121-202 & 135-31

2/10/89(3/20/91)

10. REVISED STANDARDS FOR CARGO OR BAGGAGE

AMEND 25-93

2/10/98(3/19/98)

COMPARTMENTS (TRANSPORT)-CLASS D TO C

AMEND 121-269

2/10/98(3/19/01)

11 HEAT RELEASE- INTERIOR MATERIALS AMEND

25-61 & 121-1897/10/86(8/20/88 & 8/20/90)

AMEND 25-66 & 121-198

8/19/88(9/26/88)

12. SMOKE DENSITY-INTERIOR MATERIALS

AMEND 25-66

8/19/88(8/20/90)

13 CREWMEMBER PBE-FLIGHT ATTENDANTS

AMEND 121-193

5/26/87(7/6/89)

& FIRE CONTROL TRAINING

AME

ND 121-204

5/17/

89(1/30/90)

AMEND 121-212

2/9/90(2/18/92)

TSO-C116 3/1/90

14. PASSENGER PBE (1) SAE

AS8048(EUROCAE ED-65)

4/30/91

POLICY LETTER

9/28/95

15. THERMAL/ACOUSTIC INSULATION

NPRM

00-09 9/8/00

FLAMMABILITY STANDARDS

16. HALON REPLACEMENT

FAA/CAA/TCAG R&D

17. CABIN WATER SPRAY SYSTEM (1)

FAA/CAA/TCAG R&D

(1) 1984 Cabin Safety Conference/Workshop

Recommendations

(2) 1985 Emergency Evacuation Task Force

Recommendations

TABLE 3. EMERGENCY EVACUATION

PROJECT/SUBJECT FAA

ACTION ISSUED(COMPLIANCE)

1. IMPROVED WATER SURVIVAL EQUIPMENT (1)(2)

NPRM 88-11

6/27/88

2. LIFE PRESERVERS (1) TSO

C13f 9/24/92

3. EMERGENCY EVACUATION SLIDES, RAMPS

TSO-C69c

8/18/99

AND SLIDE/ RAFT COMBINATIONS (1)(2)

4. SURVIVOR LOCATOR LIGHTS

TSO-85a

3/7/96

5. SURVIVAL EQUIPMENT IN OVERWATER OPS (1) AC 120-47

6. EMERGENCY EXIT DISTANCE

AMEND 25-67 & 121-205

6/16/89(7/24/89)

UNIFORM DISTRIBUTION OF EXITS (1)(2) AC

25 807-1

8/1

3/90

7. ACCESS TO TYPE III EXITS (2)

AMEND 25-76, 121-228 & 135-43

8. TYPE AND NUMBER OF PASSENGER

AMEND 25-88

EMERGENCY EXITS (TRANSPORT) (2)

9. EXIT ROW SEATING

AM

END 121-214 & 135-36

10 EMERGENCY EVACUATION DEMONSTRATIONS AC

20-118A

3/9/87

FOR COMMUTERS

11. MISCELLANEOUS CHANGES TO EMERGENCY

AMEND 25-79 &121-233

8/19/93(9/27/93)

EVACUATION DEMONSTRATION PROCEDURES (2) AC

25.803-1 11/13/89

12. PA SYSTEM INDEPENDENT POWER SOURCE (1)

13. AIRCRAFT PORTABLE MEGAPHONES TSO-C137

14. CREWMEMBER EMERGENCY TRAINING/ AC 120-48

RESOURCE MANAGEMENT CREWMEMBER

ACOB 1-94-30 8/25/94

COMMUNICATION & COORDINATION (1)(2)

15. PASSENGER BRIEFING (1)(2) AC 121-24A(-24B)

16. CARRY-ON BAGGAGE MEASURE & LIMIT (1)(2) AMEND 121-194

17. EMERGENCY EQUIPMENT SDR (1)(2) AMEND 121-195

18. MISCELLANEOUS CABIN SAFETY CHANGES NPRM 96-9

FOR FLIGHT ATTENDANT ASSIST

19. EMERGENCY EVACUATION DEMONSTRATION NPRM 95-9

INJURY REDUCTION

(1) 1984 Cabin Safety Conference/Workshop Recommendations

(2) 1985 Emergency Evacuation Task Force Recommendations

附錄十九

駕駛艙影像記錄爭議與解決

What improvement do we get from cockpit video?

By

Awad Thomas Fakoussa

AWARENESS TRAINING

What improvement do we get from cockpit video?

Awad Thomas Fakoussa - F 03366
Awad Thomas Fakoussa, born 1948 in Port Said, Egypt. Grew up in Germany and became a pilot. He flew as flight instructor in professional pilot schools and also as captain on B 737's apart from studying psychology and running seminars about the art of learning, teaching, CRM, management training etc. Since 1994 facilitated the new art of **P**ersonal **R**esource **M**anagement – **PRM**

The subject of this paper is to share with mainly technically oriented Air Safety Investigators the human factors knowledge about voice and body language analysis for accident investigation and to decide (on the basis of science and rationality) thereafter, what advantages do we get from videos and what could be possible disadvantages.

You are all familiar with the British Midland 737-400 accident (left engine broken, right engine shut down). What could have prevented this accident? The cabin attendants saw the flames, smelled the burning oil and saw the smoke in the cabin. None reported to the purser/cockpit what was going on. What did the captain not see, that was yet visible? – Body language and voice signals! If you take off as a captain not being aware of the cabin attendants body language and voice signalling : I will not enter your cockpit with whatever message ! then his first take off is already a high risk. Would everybody see those warning signals – certainly not without an intensive training.

(Short personal example, not for publication)

Can you already see what I am getting at??

In the past we installed voice recorders without giving the accident investigators a proper in depth training about voice analysis and all the different signals a voice is transmitting. Words are only a very small part of communication. The result was, that despite a few human factors specialists being consulted and giving more information (about the contained feelings, the hierarchy gradient, the underlying aim etc.), the accident investigator in charge did not have a real and complete overview about what that meant in connection with the motoric actions of the pilots. The pilots motoric actions are visible in the flight path and performance etc. These data are available on

QAR and any other highly sophisticated black box. Did accident investigators connect these data to the emotions expressed in the voice? – In many cases yes. Did they than connect it to the brain performance – NO!!

If I tell you as a pure human factor specialist, all the data the voice gives me – can you really and fully understand all the implications involved in these data?

If a cook tells you about all the secret signals of herbs and spices and how he uses them to modify or intensify taste of food – do you really and fully understand what he means?

If you tell me about a certain special food from your country, your state, your home town - do I really and fully understand what you mean?

Example:
Tell me, how do you like Molochia? - You do not know what that is?
So we will call a specialist, by accident I am one:
I am Egyptian and it is an Egyptian vegetable. It is green, looks like spinach and is being cooked like spinach and tastes completely different from spinach. - Do you have now any idea what I am talking about and how it would fit in with roasted turkey?? I know it would fit in nicely with the turkey meat but only if you do not serve potatoes with it.
Why?
I have eaten turkey before. I have eaten Molochia before. I can connect the data to find out, what matches and what does not.

So if you have a human factor specialist and an extremely well qualified accident investigator, both will not have the complete picture with all the connections and implications of what happened in that cockpit.

So because of installing (once again) all the technically possible equipment but not training the specialists to work with it, we will end in a cul-de-sac. First we needed the voice recorder do understand what was really happening in the cockpit, now this is not enough, we want the videos installed and in 2 decades or even earlier we will need the heartbeat and blood pressure and thereafter we will connect the pilots brain directly to the QAR.
But if we had trained accident investigators to be expert specialists in analysing voice and language in a easy and in depth way, could we not save a lot of money and

trouble. And could that knowledge perhaps improve as a nice side effect your relationship at home as well, with your spouse, your children, your family ?

The body language only shows, what the voice expresses anyway. Did you ever see an Italian on the phone NOT moving around?? So there you can see what you hear anyway. All you need is a bit of knowledge and experience.

Basically we are all experts already in voice and body language analysis, but not on a conscious level. We analyse non-consciously and therefore we have no conscious control over the development of the communication process. And do not tell me, you have that control or I will ask your spouses tonight at the dinner about that.

The disadvantages:

The problems that we are getting with video observation is worse than what we achieve because:

- Who of you people likes being stared at when working??

Same for the pilots. The problem is, if you do not feel ok in a situation, that a certain part of your brain will release hormones that might disturb other parts in functioning well. The typical example is a check or exam.

  - Who of you people likes or perhaps even enjoys being checked or examined?

If you do not like being checked, does your performance improve? So why do you think pilots would get better, if the video of their performance can be seen by millions of TV watchers one day. Do not say, that this will not happen, just search the internet for voice recorders.

If pilots in addition get threatened with punishment (New Zealand, Singapore Airlines wrong runway for TO e.g.) what performance do you now expect? Are we getting safer aviation by producing less safe pilots performance?.

So instead of loading more pressure on the pilots let us understand first and gain all the available information from a voice recorder. In the workshop we showed you already how easy that is and that you all could become experts quite quickly in that field.

During the paper presentation there will be a short example analysis demonstrated of a transcript that will be based on any actual voice recording of any accident.