出國報告（出國類別：進修）

美國洛杉磯南加州安全學院
航空維修人爲因素訓練出國報告

服務機關：行政院飛航安全委員會
姓名職務：失事調查官／李寶康

派赴國家：美國
出國期間：民國 99 年 8 月 9 日至 8 月 14 日

報告日期：民國 99 年 10 月 1 日

目次

壹、目的

統計國際間發生之飛航事故，發現有 60~70%皆人爲過失所致，深入研究發現所有事故追朔其因，結果發現皆爲駕駛員，航管員，維修員，航空器製造廠，經理人甚至航空業監理機關等人爲過失。有鑑於此航空業界開使注意人爲因素並紛紛引入各種人爲因素之研究。

初期針對事故率最高之飛航駕駛員之人爲因素進行研究，於 1978 年 12 月 28 日，發生聯美航空（United Airlines）173 班機於美國奧勒岡州波特蘭之失事案件後，便發展了「組員資源管理（Crew Resource Management, CRM）」訓練，該訓練是提供給駕駛艙內作業之組員針對人與人間之溝通、協調、互助、合作等人爲因素方面之訓練。

於 1988 年 4 月 28 日，發生阿囉哈航空（Aloha Airlines）243 班機於美國夏威夷之失事案件，調查發現該事故原因係當時飛機結構維修系統未能偵測高齡機經修補後之蒙皮結構潛藏之危機，便發展了「維修人爲特性（Human Performance in Maintenance, HPIM）」訓練，該訓練是提供給飛機及機坪作業之機械員針對人與人、事、物間之溝通協調等人爲因素方面之訓練。

又於 1989 年 4 月 10 日，發生安大略航空（Air Ontario）1363 班機於加拿大安大略踐登之失事案件，調查發現該事故原因係當時飛機維修人員未能遵守公司之交接班規定，使飛機維修作業不完整，發生飛航之危機，於是又發展了最新一代的「飛機維修之人爲因素（Human Factor in Aircraft Maintenance System, HFAMS）」訓練，該訓練是提供給航空器作業之所有人員，包括機械員及管理人等，針對人與、事、物間之溝通協調及事故發生後之訓練計畫等人爲因素方面之訓練。

本次接受之訓練乃係最新一代的「飛機維修之人爲因素（Human Factor in Aircraft Maintenance System, HFAMS）」訓練。課程設計之目標爲，完訓後能透過

人因技巧之運用，增進維修任務執行之有效性及安全性；於態度及行爲上有可見之改變；航空維修人因制度化。工作室小組作業目標爲，於飛機修護作業方面增進人類警覺性；人因訓練益處與重要性之知識；協助你評估、提倡或發展組織內人因訓練之工具。

參與此課程的學員除本人來自台灣飛航事故的調查機構外，尚有 10 人來自美國各大航空公司及軍方的維修單位，另有 1 人來自加拿大的 First Air 航空公司，共 12 人，分別來自 3 個國家。

貳、過程

受訓期間	課程主題
8 月 10 日 第一天	0800 歡迎及介紹（Welcome and Introduction） 0900 主題，目標及參考資料（Objective, Goals & Takeaways） 0930 歷史及美國民航局相關規則及指令 History & FAA Regulations/Guidance） 1000 人因定義，重要性及統計（HF Definitions, Importance & Statistics） 1100 人爲過失（Human Error） 1200 午餐（Lunch） 1300 維修疏失（Maintenance Error） 1400 監理及組織疏失與共識(Supervisory and Organizational Errors & Norms） 1500 規矩，決心下達（Ethics, Decision Making） 1530 維修案例研討（C-130 Maintenance Case Study）
8 月 11 日 第二天	0800 衰弱的人類表現（Diminished Human Performance） 0900 狀況警覺（Situation Awareness） 1000 溝通（Communications） 1100 溝通練習（Communications Exercise） 1200 午餐（Lunch） 1300 程序及模型運用（Process Application/Model Adaptation） 1400 衝突解決（Conflict Resolution） 1500 事件介紹（Event Introduction） 1600 鷹湖事件介紹（Introduction to Eagle lake）

8 月 12 日 第三天	0800 案例研討工作小組（Case Study Workgroup） 1000 小組演講（Team Presentations） 1100 人因訓練課程發展（HF Training Program Development） 1200 午餐（Lunch） 1300 人因訓練課程發展（HF Training Program Development） 1400 課程介紹（Program Presentation） 1530 總結（Summery/Review） 1600 測試與問卷（Test & Critique） 1630 畢業與發證（Graduation）

圖 2-1 教師授課情形

圖 2-2 學員討論情形

叁、心得

➢　維修人因訓練之益處

某大航空公司連續 12 個月的人因訓練後，發現變化如下：

- 地面損害修理成本降低 68%
- 維修相關地面損害降低 34%
- 職業傷害時數減少 27%
- 職業傷害醫療給付減少 12%

距美國西雅圖南方 40 哩 Tacoma 機場 1 哩的 McChord AFB，是美國在華盛頓的空軍基地（詳圖 3-1），其統計資料顯示從事飛機維修業務之相關人員，於接受維修資源管理人因（MRM）課程訓練前後，維修品質差異之情形（詳表 3-1，圖 3-2）。

圖 3-1 美國華盛頓 McChord AFB 空軍基地

表 3-1 接受維修資源管理人因（MRM）課程訓練前後維修品質差異表

單位：件數

類別＼年度	2005/03 ~ 2006/03	2006/03 ~ 2007/03
品保檢查	3,702	4,991
違反安全標準	44	20
違犯技術資料規範	28	14
物件遺留	120	54
總事故	154	129

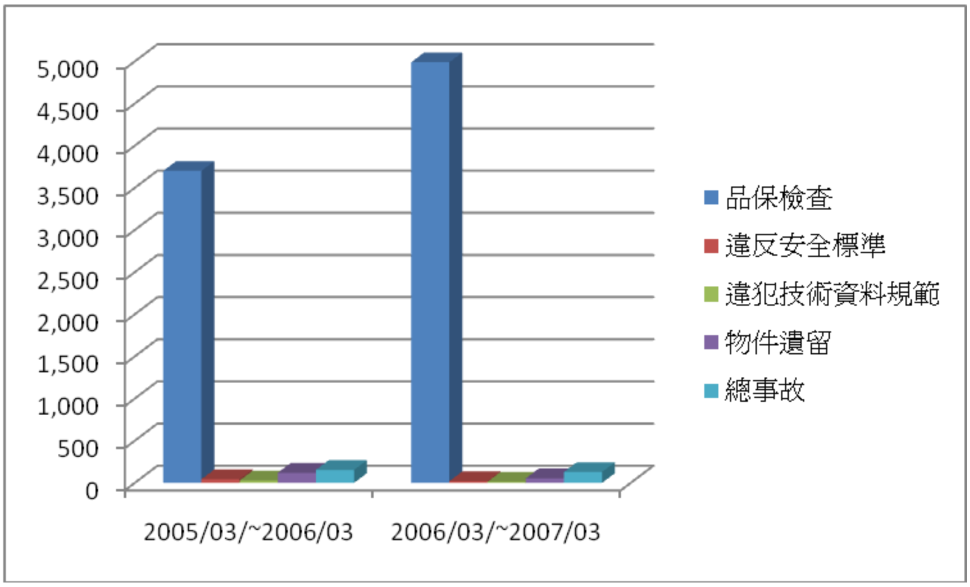


圖 3-2 統計資料顯示接受 MRM 人因訓練前後之維修品質差異

統計該空軍基地飛機維修品質於接受 MRM（維修資源管理）訓練後一年內所執行之飛機品保檢察共 4,991 件，較訓練前一年內所執行之飛機品保檢察共 3,702 件多了 1,289 件，佔了訓練前一年所執行之飛機品保檢察件數的 1/3，但違犯安全事件卻少了 24 件，這佔訓練前違犯安全件數的 1/2 強；技術資料違犯件數亦由訓練前的 28 件降到 14 件，爲訓練前違犯件數的 1/2；物件遺留件數由訓練前的 120 件降到 54 件，將近訓練前物件遺留件數的 1/2；飛機總事故件數亦由訓練前的 154 件降到 129 件，由這統計數字要說完全是 MRM 訓練的效果可能有些困難，但應可看出人因訓練對維修作業產生影響的趨勢。

➢ 工作室（workshop）概念：分成人因基礎為一塔之底部、人因應用及發展訓練三大類，詳圖 3-3。

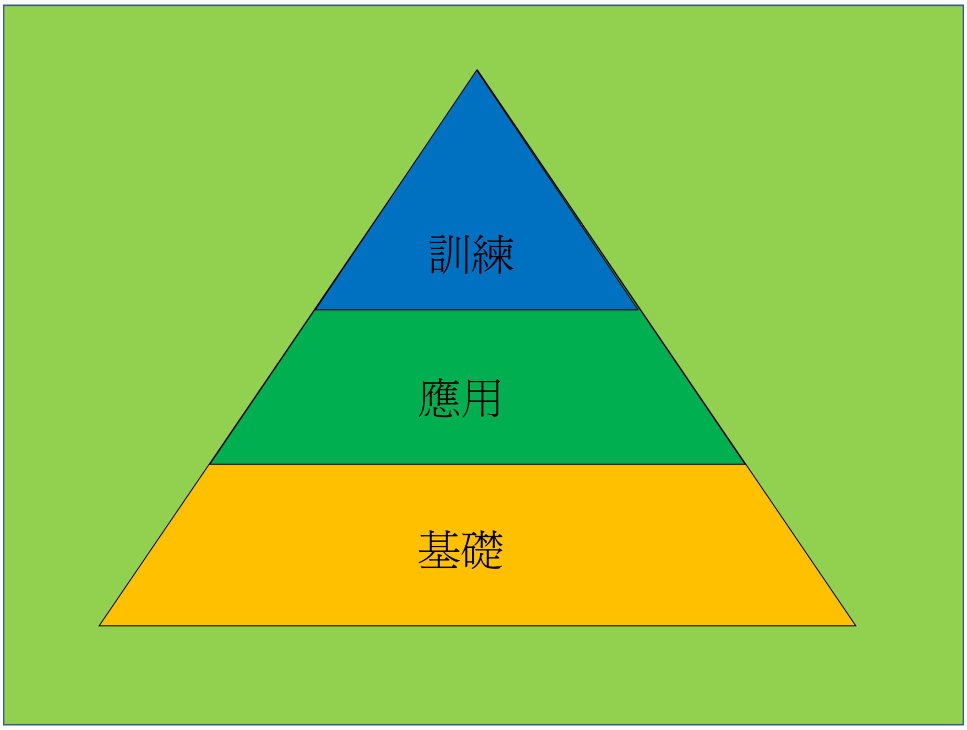


圖 3-3 工作室（workshop）概要分成人因基礎、人因應用及發展訓練三大類

■ 基礎：內容包括人因之緣起及美國民航局規則、人因之定義、統計資料、人為過失、緊張及疲勞、狀況警覺、溝通及障礙等基本常識（詳圖 3-4）。

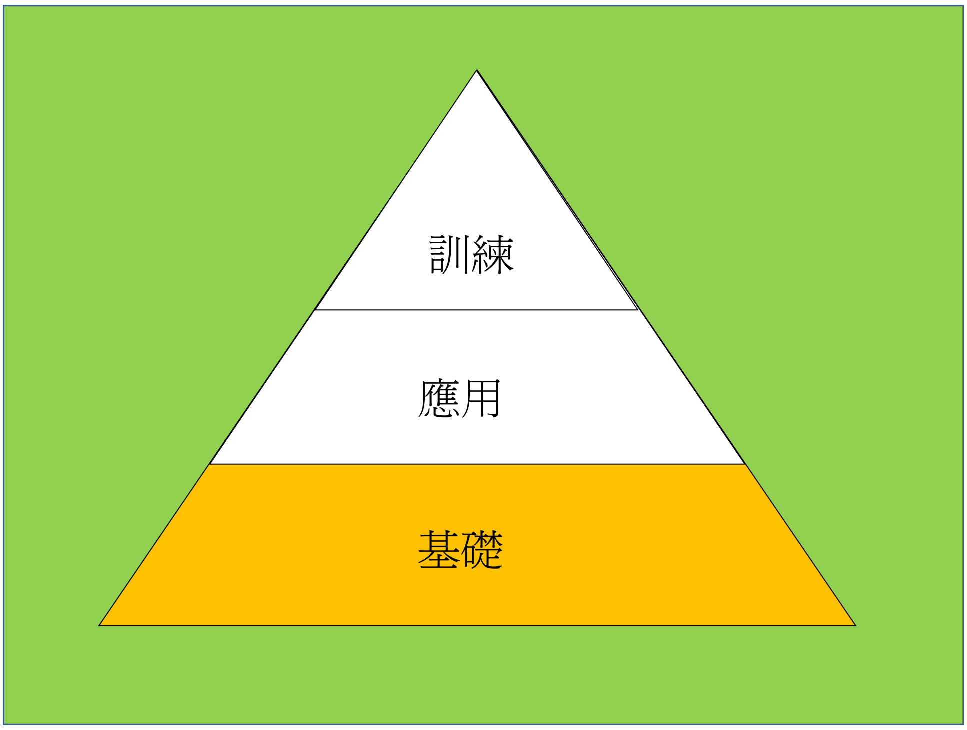


圖 3-4 工作工廠之基礎

基礎

➢ 緣起及美國民航局規則

民航業界初期針對事故發生率最高之飛航駕駛員之人為因素進行研究，於1978 年 12 月 28 日，發生聯美航空（United Airlines）173 班機，於美國奧勒岡州波特蘭之失事案件，調查發現事故原因爲降落時發生飛機起落架障，駕駛員因專注精神在準備起落架故障外型下落地，忽略了燃油存量，副駕駛員雖然發現問題但與正駕駛員之間的溝通無效，以致發動機在燃油耗盡情況下失去動力，飛機墜毀在距機場西南方 6 海浬有住宅的樹林內。機上載有 181 名乘客與 8 名機組人員，8 名乘客與飛行機械員及 1 名空服員喪生，21 名乘客及 2 名空服員重傷。事件後便發展了「組員資源管理（Crew Resource Management, CRM）」訓練，該訓練是提供給駕駛艙內作業之組員針對人與人間之溝通、協調、互助、合作等人爲因素方面之訓練。

於 1988 年 4 月 28 日，發生阿囉哈航空（Aloha Airlines）波音 737-200，243 班機

於飛往美國夏威夷 24,000 呎高度之航路上，發生爆炸性洩壓及飛機結構失效之案件，當時機上載有 89 名乘客與 6 名機組人員， 1 名空服員喪生，7 名乘客及 1 名空服員重傷（詳圖 3-5）。調查發現該事故係飛機結構維修系統，未能偵測高齡機經修補後之蒙皮結構潛藏之危機，及美國民航局監理疏失等原因，之後便發展了「維修行爲特性（Human Performance in Maintenance, HPIM）」訓練，該訓練是提供給飛機及機坪作業之機械員針對人與人、事、物間之溝通協調等人爲因素方面之訓練。

圖 3-5 阿囉哈航空（Aloha Airlines）發生爆炸性洩壓及飛機結構失效之案件

又於 1989 年 4 月 10 日，發生安大略航空（Air Ontario）1363 班機於加拿大安大略踐登之失事案件，調查發現該事故原因係因組織文化之不健全，員工忽視公司規定，致使飛機在 APU（輔助電力單元）失效及機翼積雪情況下起飛而肇致事故，於是又發展了最新一代的「飛機維修之人爲因素（Human Factor in Aircraft Maintenance System, HFAMS）」訓練，該訓練是提供給航空器作業之所有人員，包括機械員及管理人等，針對人與、事、物間之溝通協調及事故發生後之訓練計畫等人爲因素方面之訓練。

國際民航組織 ICAO 在一連串事故後，於 1998 年發布有關維修人因訓練之手冊（Human Factor Training Manual），美國交通部民航局 FAA 亦於 2005 年發布航空維修人因操作人手冊（Operator’s Manual for Human Factor in Aviation Maintenance）及維修資源管理通告（Advisory Circular AC 120-72 Maintenance Resource Management），歐盟民航安全機構（European Aviation Safety Agency, EASA）之安全規則分組（Safety Regulation Group）發布 145 部下授權之維修廠，其人因及管理規則之民航維修人因指導教材 CAP 716 Aviation Maintenance Human Factors （EASA / JAR145 Approved Organisations） Guidance Material on the UK CAA Interpretation of Part-145 Human Factors and Management Regulations

何謂人因

- 佔最大比例的肇事因素
- 各專業領域的人因工程
  - 認知科學
    - 專注於人對資訊的處理
    - 人與電腦介面之設計
    - 資訊的呈現
    - 生理負荷
    - 人為判斷錯誤
  - 人體測量工程
    - 專注於人的量測
    - 使裝備／系統配合人的特性

- 醫療裝置
- 為易於維護而設計

■ 工業工程

- 專注於工作中的人
- 對工作進行系統性分析
- 工作程序之設計
- 顯示器／旋鈕／刻度表之設計
- 製造與辦公室自動化

■ 電腦科學

- 是一門包含各種各樣與計算和資訊處理相關主題的系統學科，從抽象的演算法分析、形式化語法等等，到更具體的主題如程式語言、程式設計、軟體和硬體等。
- 電腦科學研究的課題是：
  - 電腦程式能做什麼和不能做什麼（可計算性理論）；
  - 如何使程式更高效的執行特定任務（演算法和複雜性理論）；
  - 程式如何存取不同型別的資料（資料結構和資料庫）；
  - 程式如何顯得更具有智慧（人工智慧）；
  - 人類如何與程式溝通（人機互動和人機介面）。

■ 安全科學

- 基礎理論

- 災害物理學
- 災害化學
- 災害學
- 災害毒理學

◆ 研究領域

- 火災安全科學與工程
- 安全系统學
- 安全心理學
- 安全仿真學
- 安全人機學
- 安全法學
- 安全經濟學
- 安全管理學
- 安全教育學
- 安全工程
- 職業衛生工程
- 安全管理工程

■ 醫療科學

◆ 是處理健康相關問題的一種科學，以治療和預防生理和心理疾病和提高人體自身素質爲目的。狹義的醫學只是疾病的治療，但也有說

法稱預防醫學爲第一醫學，臨床醫學爲第二醫學，復健醫學爲第三醫學。醫學的科學面是應用基礎醫學的理論與發現，例如生化、生理、微生物學、解剖、病理學、藥理學、統計學、流行病學等，來治療疾病與促進健康。然而，醫學也具有人文與藝術的一面，它關注的不僅是人體的器官和疾病，而是人（身體和心理）的健康和生命。

- 實驗心理學
  - 將心理學作爲一門自然科學處理，假定它可以採用實驗方法。該分支更注重的是研究方法。實驗心理學的建立使心理學擺脫了哲學心理學的階段，進入了科學心理學的階段`。
- 工業與組織心理學
  - 是應用心理學的一種，屬於組織行爲學的範疇，主要是分別員工、顧客及消費者的心理層級，包含招聘、從眾多應徵者中選用員工，並包含對員工的訓練、績效評價、工作滿意度、工作行爲、工作壓力管理。
- 教育心理學
  - 是研究在教育情境下人類的學習、教育干預的效果、教學心理，以及學校組織的社會心理學。教育心理學的重點是把心理學的理論或研究所得應用在教育上。教育心理學可應用於設計課程、改良教學方法、推動學習動機以及幫助學生面對成長過程中所遇上的各項困難和挑戰。

➢ 調查報告顯示所有事故有 60-70%皆與人爲過失有關。深入分析發現所有事故皆可追朔致人爲過失，如果非駕駛員或管制員的疏失，那就是機械員，製造

者，管理人或其他航空界的專家包括監理機關。

- 影響人類與活動介面之要素。
- 訓練能有效地使人類與活動間之介面趨於完美。
- 必須經各種學問的努力，來發現並彙整有關人類的能力與極限，並將該資訊應用在裝備，系統，設施，程序，工作，環境，訓練，僱員，及管理安全、舒適及效率的人員上。（FAA Order 9550.8）
- 是有關人們在其工作及生活環境，有關他們與裝備，程序及環境之間的關係，尤其重要的是，他們與其他人的關係，安全與效率為其目的。（ICAO Circular 227）
- 是一種人類如何與環境互動之研究。以民航來說，是有關如何駕駛艙的設計、空氣溫度與高度、人體器官的功能、不同情緒、與其他民航業者的互動及溝通，如組員及管制員等，影響駕駛員表現。（Transport Canada）
- 人們與活動間之完美紀律，藉由人類科學整合在系統工程的框架內。（Elwyn Edwards）

統計

國際間航空公司於 2006 年發生重大事故肇事原因統計發現，航空器於可控制情況下撞擊地形者（Control flight into Terrain）有 6 件；人為因素者（Human Factors） 12 件；機械失效者（Technical/Maintenance）7 件；不明原因者（Unknown）5 件（詳圖 3-6）。

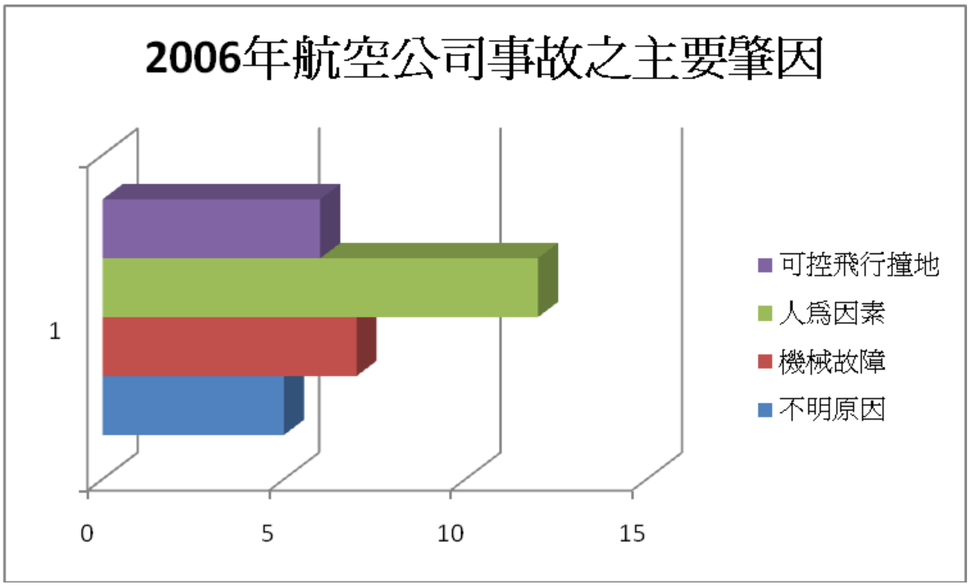


圖 3-6 國際間航空公司於 2006 年發生重大事故肇事原因統計

美國空軍自 1992 年至 2005 年，源自人因肇事之死亡事故，統計發現占了總事故率的 92%，其他原因則佔 8%（詳圖 3-7）。

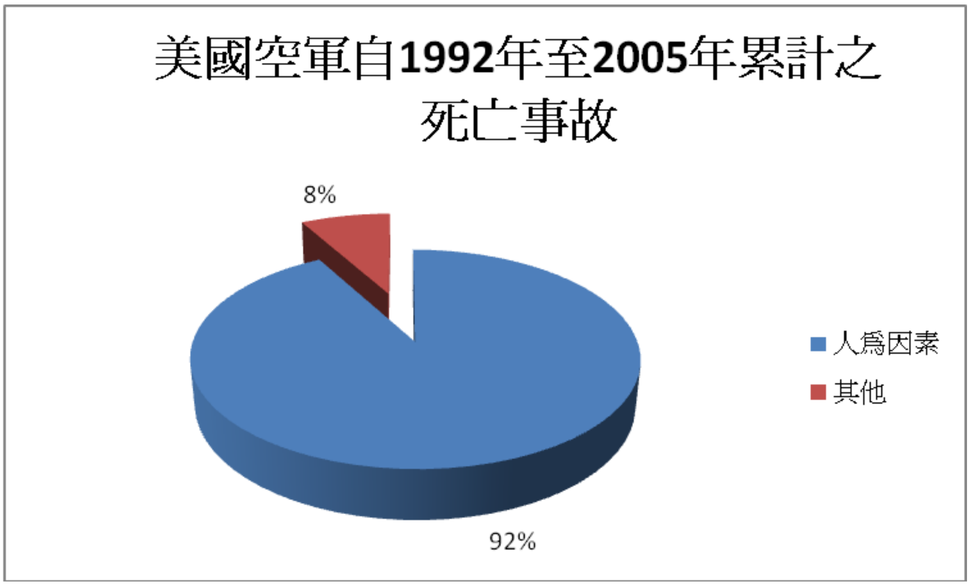


圖 3-7 美國空軍自 1992 年至 2005 年，源自人因肇事之死亡事故統計

由國際間之航空公司及美國空軍自 1992 年至 2005 年連續 8 年之事故統計資料，顯示人因皆爲主要事故肇因。

人爲過失（Human Error）

- 人是會犯錯的。
- 有計劃的行動未能達成原來之期望，不論是行動未照計畫進行，或是因爲計畫本身的缺失。
- 違規（Violation）：人的活動有蓄意偏離公司或監理機關之政策或程序者。

    1. 三種違規的模式：例行（Routine）；視狀況（Situational）；例外（Exceptional）

- 違規之定義：

例行（Routine）：係一般性，普遍性，自然發生的某種作業方式。這種違規模式已形成一種團體性的作業方式。例行違規通常爲經理人所默許，亦爲監督者所接受。

視狀況（Situational）：通常是因爲當事人週遭之工作性質、場所或環境的因素，使機械員或檢查員偏離了正常的工作模式而扭曲了規則，這些因素包括：

1. 時間壓力
2. 督導不周
3. 裝備、工具或零件不足
4. 人力不足
5. 極端氣候

例外（Exceptional）：機械員/檢查員不考慮後果，意圖違犯既有之規定。

- 人爲過失的發生：

    1. 任何人都會犯錯

2. 源起基礎不同

3. 同樣的錯誤可能造成不同的後果

➢ 人爲過失之原理

1. 人類意識是不可靠的儀器

2. 只有小部份的人爲過失會導致災難性的後果

3. 過失是人類意識在大量機械化作業下發生些許失敗的自然結果

4. 所有過失後果無礙者，可爲後者借鏡，可視爲有益的

5. 如果過失是從系統面接近的話那顯示防禦性有低落的趨勢

6. 過失管理的基本原理之一是好的人可能發生最壞的錯誤

➢ 有意識及下意識情況下之工作表現

維修作業之執行若以性質來區分則可分成下列三類：

■ 知識性：無例行性或規則性之狀況處置

■ 規則性：如徵狀爲 X 則原因爲 Y，如原因爲 Y 則執行 Z

■ 技巧性：只須些許意識及注意可執行之習慣性自動作業

人類精神集中與專注之狀態亦可區分成兩類，即有意識（Conscious）及下意識（Automatic），這兩類精神狀態之強弱則以下圖右欄該標示區域之寬窄來對照（詳圖 3-8）。

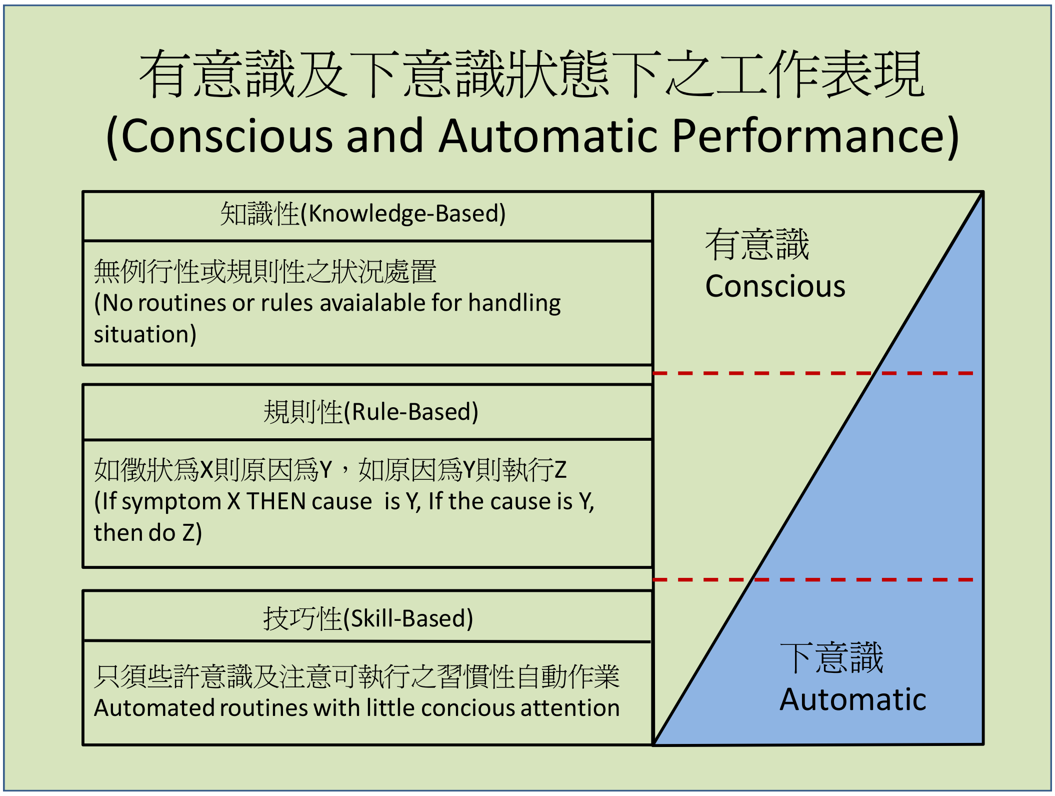


圖 3-8 有意識（Conscious）及下意識（Automatic）之工作表現對照

上圖顯示知識性維修作業對應之欄位爲較寬欄位之有意識，較小欄位之下意識，表示執行知識性維修作業時，需要較專注的意識力；規則性維修作業對應之有意識欄位與下意識欄位之寬窄相等，表示執行規則性維修作業時，意識力不需要像知識性作業般專注，同時下意識力亦等量潛入該類工作之精神狀態；技巧性維修作業對應之欄位爲較寬欄位之下意識，較小欄位之有意識，表示執行技巧性維修作業時，並不須太多過於集中精神的意識力，只需付出較輕鬆的下意識力即可完成任務。研究發現人腦會自動調整用腦的程度，不須使用腦力的情況它會自動將精神狀況調至下意識經神情況。這好處是下意識經神情況可節省體力消耗，但壞處是下意識精神情況容易發生錯誤。

➢ 自滿（Complacency）：

■ 伴隨自滿而來的即是失去狀況警覺。

■ 組成自滿之兩種主要元素：

- ◆ 具高水準之技術者
- ◆ 具豐富之經驗者

■ 自滿的徵兆：

- ◆ 這工作我已經做過無數次了，從來都沒有發生問題
- ◆ 感覺所有事情皆沒問題
- ◆ 這工作無趣
- ◆ 疲勞更易產生自滿

➢ 過失的種類（Types of Errors）：

■ 顯性（Active Failure）：其結果是會立刻顯現的

■ 隱性（Latent Failure）：其結果並不會立刻顯現，而是須要有時間經歷後才會顯現的

➢ 維修過失所造成的後果：

1. 統計資料顯示航空事故源自於維修過失肇因的比例佔了 12%，是排名第三的飛航事故肇因（詳圖 3-9）。

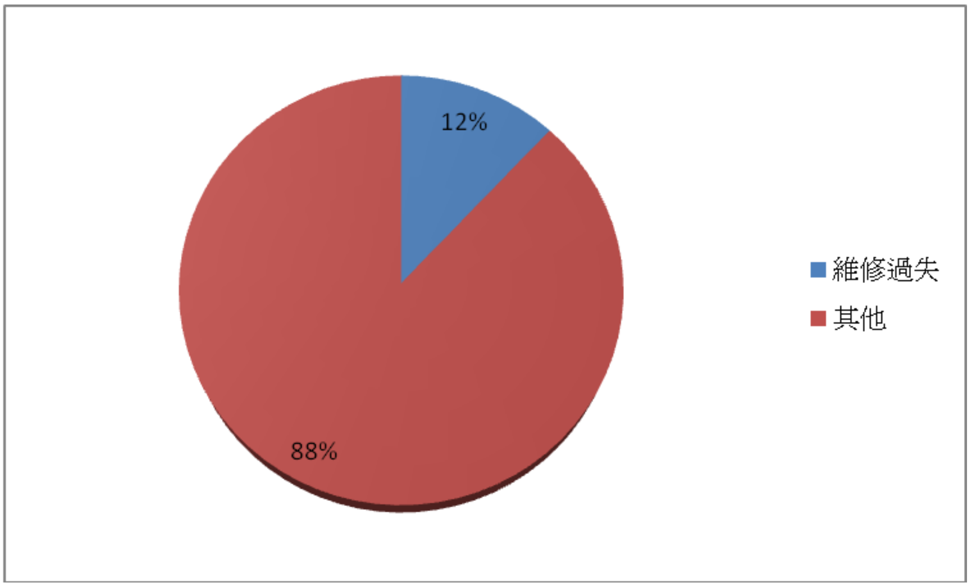
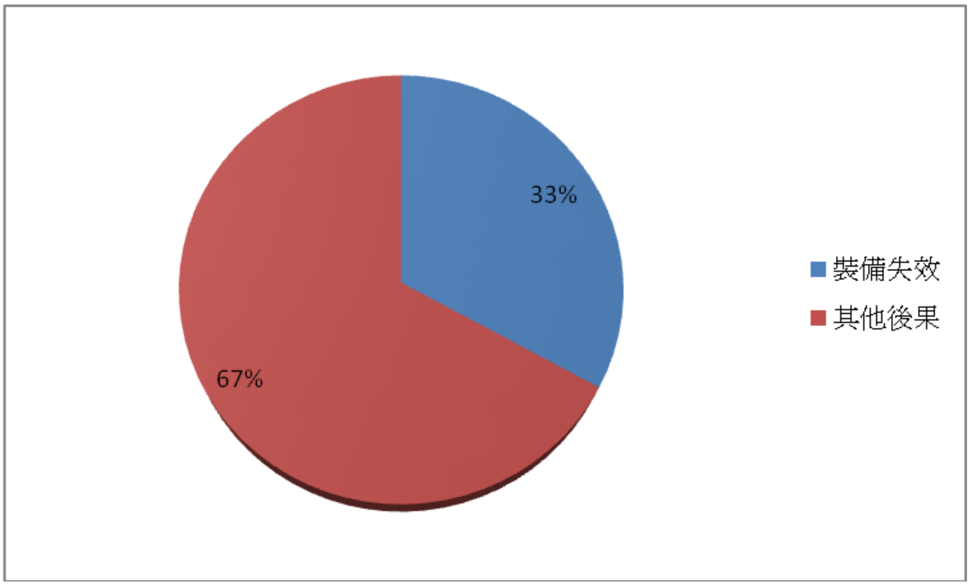


圖 3-9 航空事故源自於維修過失肇因的比例

2. 統計資料顯示源自維修過失導致的裝備失效比例佔了 33%，是自維修過失事故肇因的大宗（詳圖 3-10）。



3. 因發動機故障所導致的班機起飛延遲佔了所有班機延故比例的 43%，是所有班機延遲比例的大宗（詳圖 3-11）。

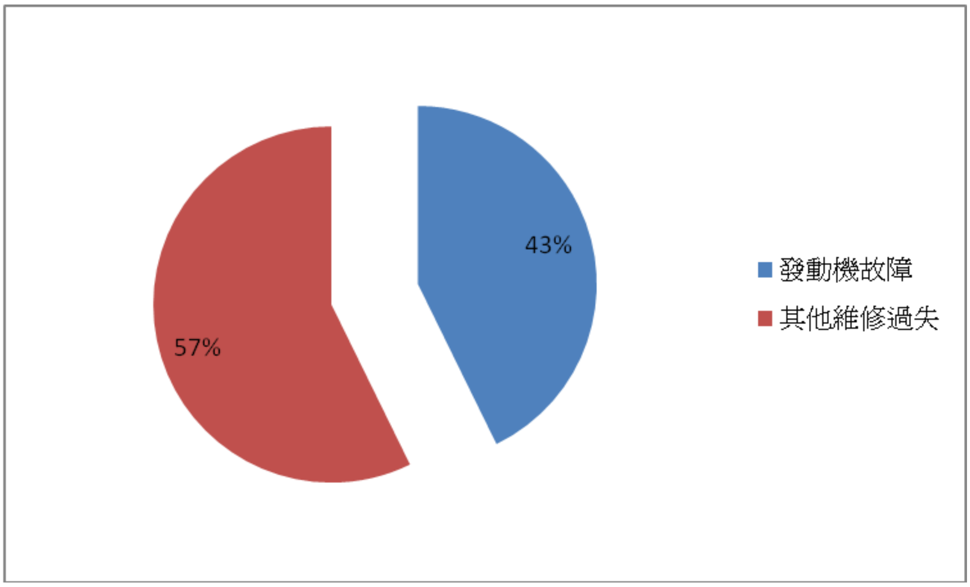


圖 3-12 因發動機故障所導致的班機起飛延遲佔了所有班機延故比例的 43%

➢ 造成維修過失的 12 主要因素及其改善方法：

1. 溝通不良（Lack of Communication）（詳圖 3-12）

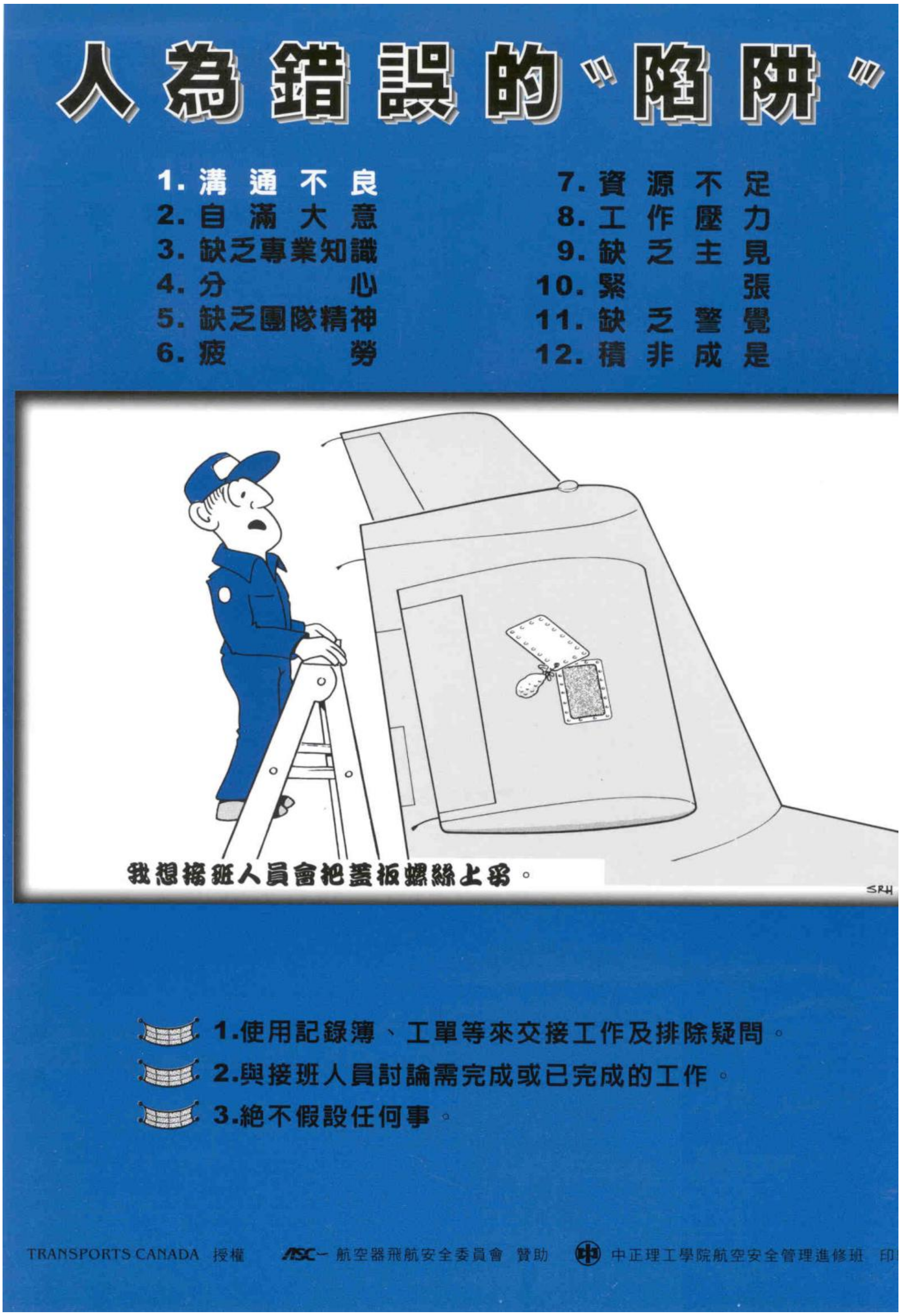


圖 3-12 溝通不良

2. 自滿大意（Complacency）（詳圖 3-13）

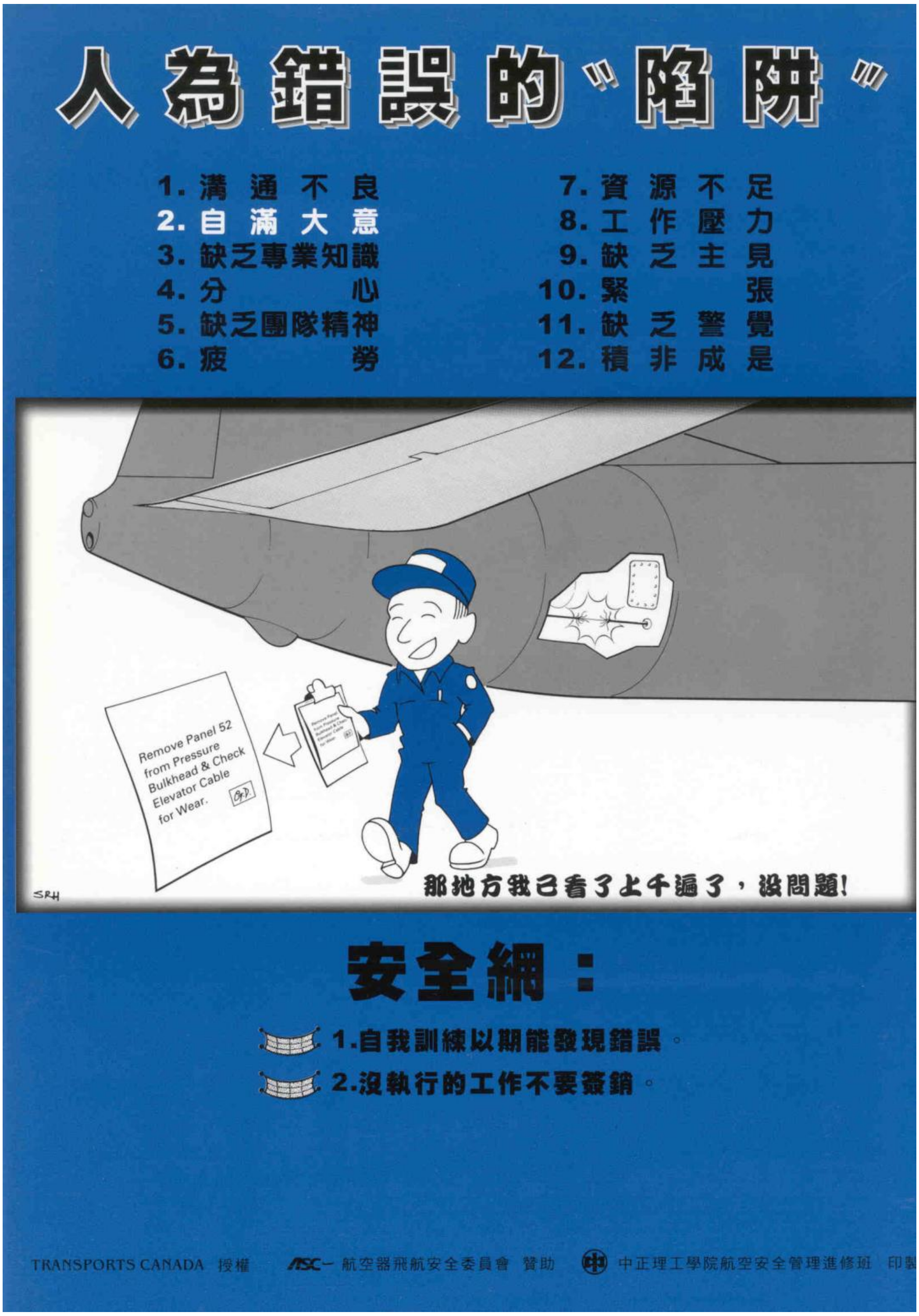


圖 3-13 自滿大意

3. 缺乏專業知識（Lack of Knowledge）（ 詳圖 3-14）

圖 3-14 缺乏專業知識

4. 分心（Distraction）（詳圖 3-15）

圖 3-15 分心

5. 缺乏團隊精神（Lack of Teamwork）（詳圖 3-16）

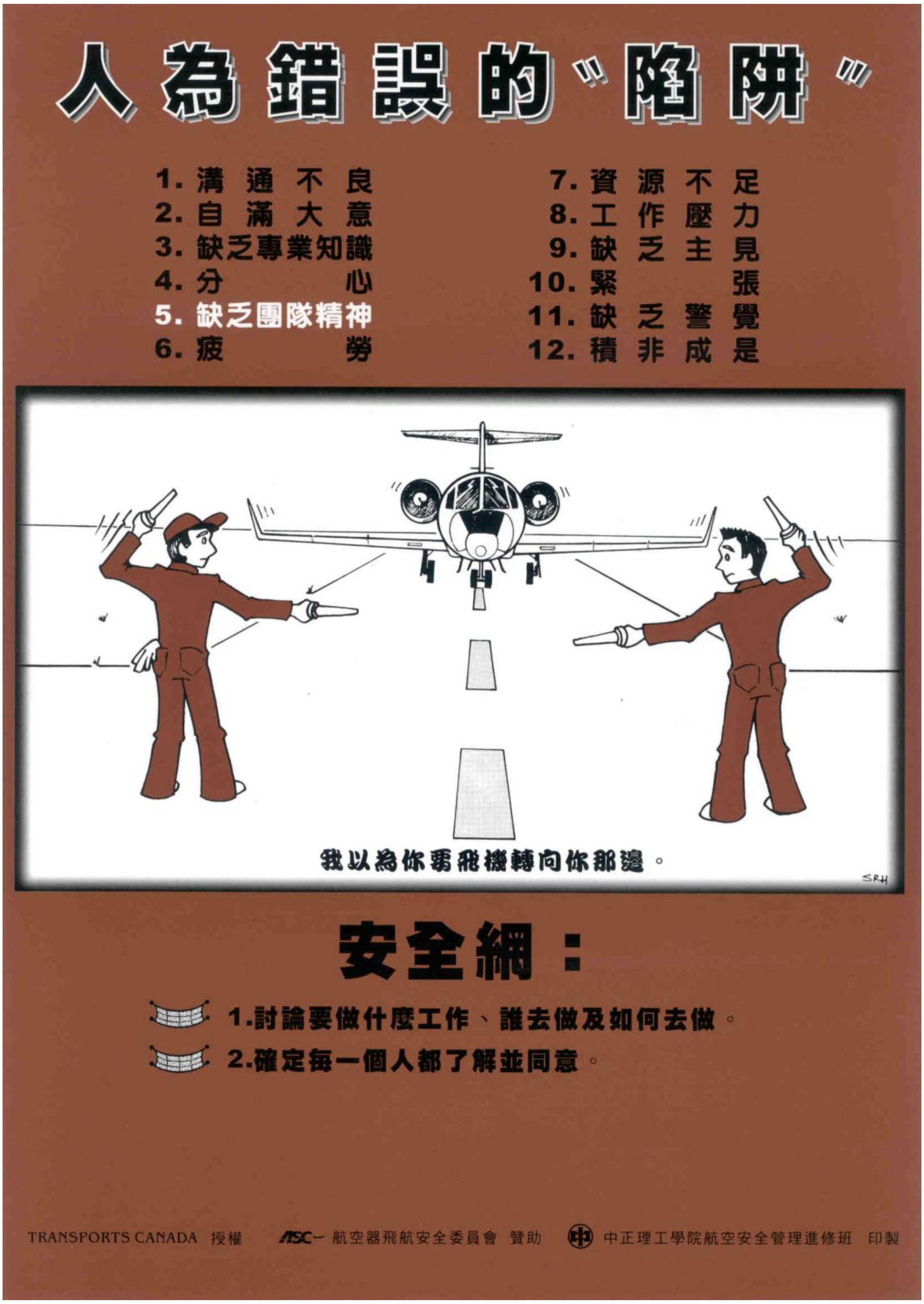


圖 3-16 缺乏團隊精神

6. 疲勞（Fatigue）（詳圖 3-17）

圖 3-17 疲勞

7. 資源不足（Lack of Resource） （詳圖 3-18）

圖 3-18 資源不足

8. 工作壓力（Pressure）（詳圖 3-19）

圖 3-19 工作壓力

9. 缺乏主見（Lack of Assertiveness）（詳圖 3-20）

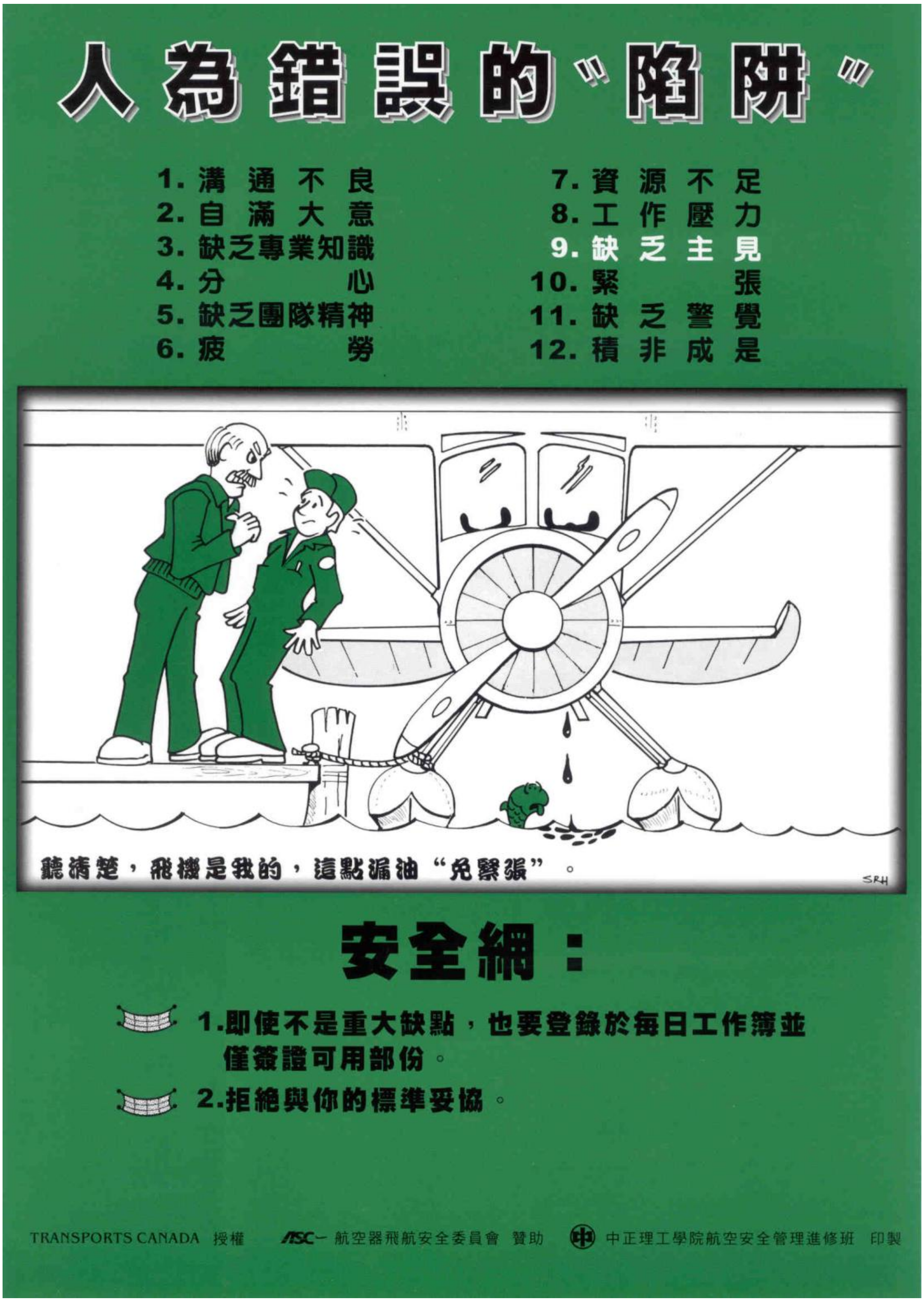


圖 3-20 缺乏主見

10. 緊張（ Stress）（詳圖 3-21）

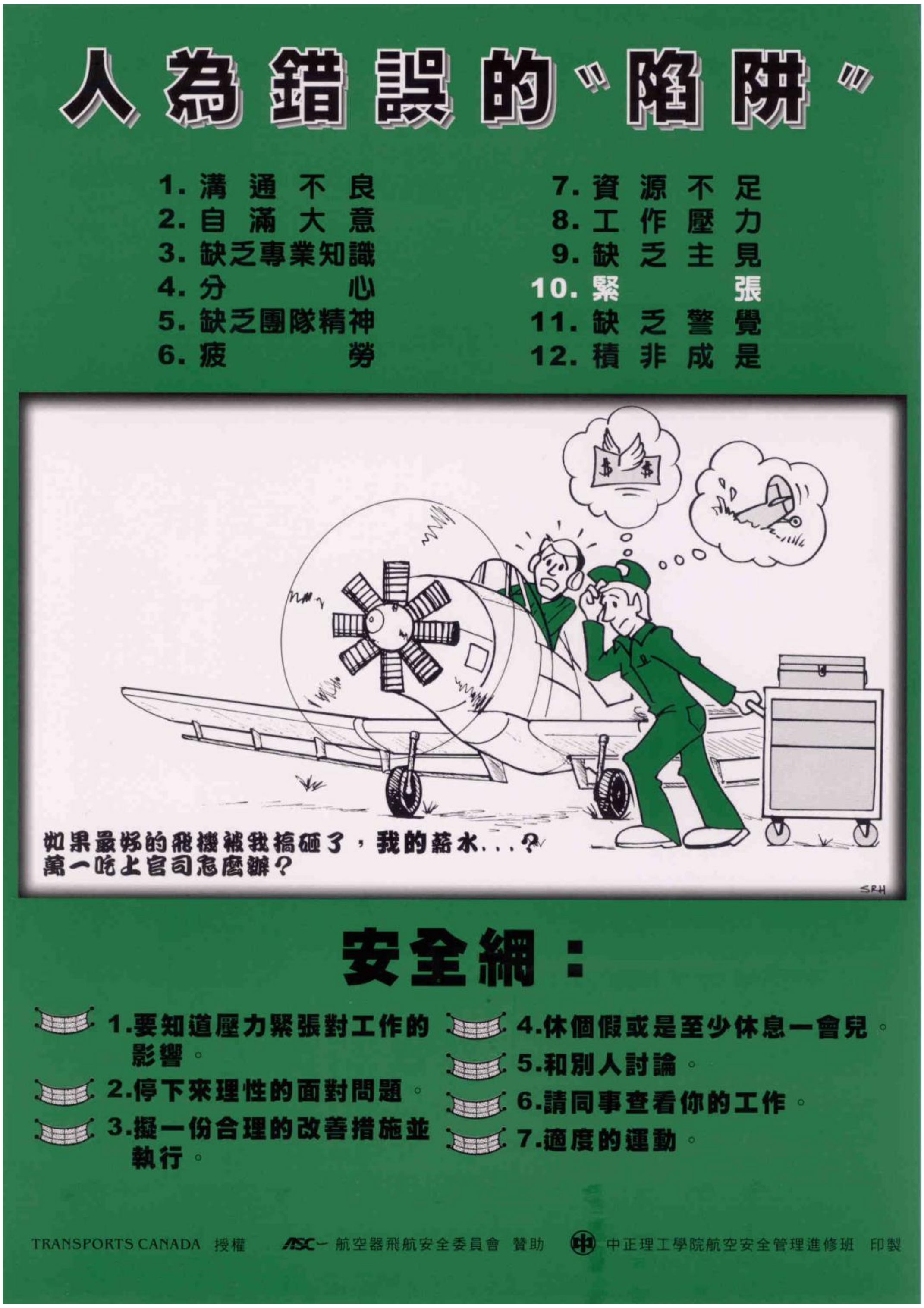


圖 3-21 緊張

11. 缺乏警覺（Lack of Awarness） （詳圖 3-22）

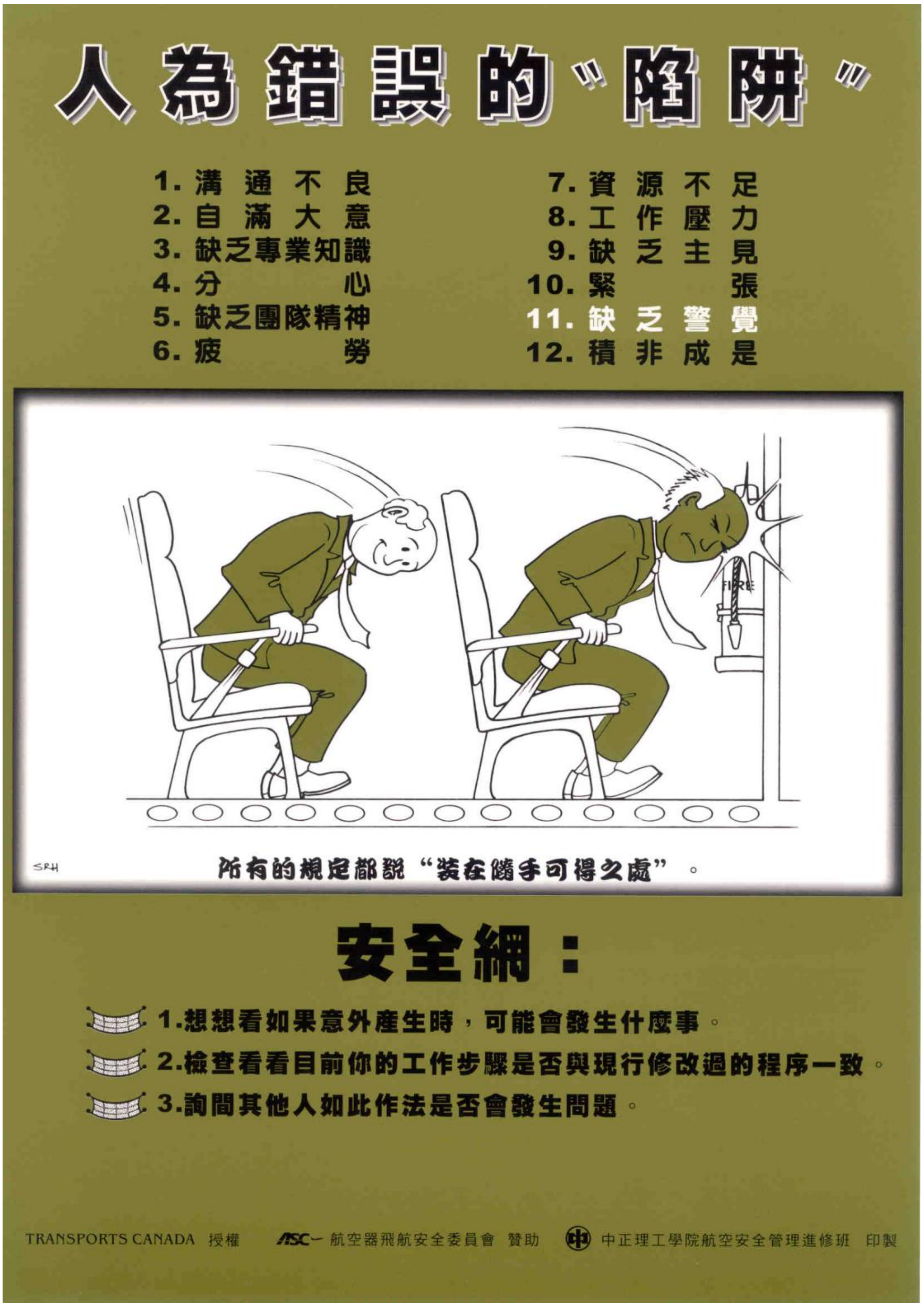


圖 3-22 缺乏警覺

12. 積非成是（Norms） （詳圖 3-23）

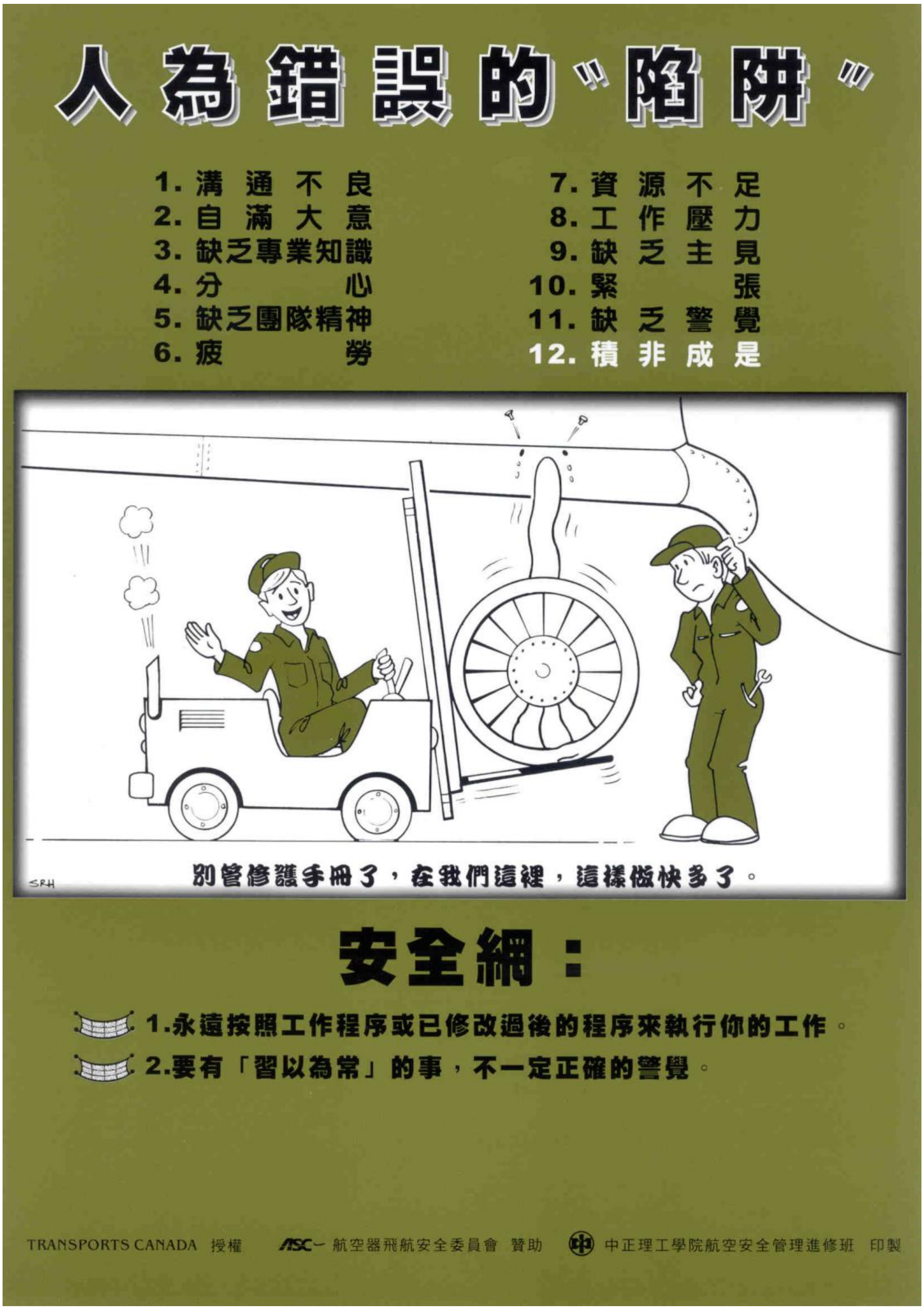


圖 3-23 積非成是

➢ 維修人因 12 戒律之對照（詳表 3-2）

表 3-2 維修人因 12 戒律之對照

缺乏	過度
溝通	壓力
資源	緊張
自信	積非成是
警覺	疲勞
團隊精神	分心
專業知識	自滿

➢ 安全網（Safety Net）

■ 組織（Organizational）性的問題：

◆ 檢查卡（Check list）

◆ 程序（Procedures）

◆ 規則（Regulations）

◆ 文化（Culture）

◆ 資源（Resources）

■ 個人（Personel） 性的問題：

◆ 工具之可靠性（Tool accountability）

◆ 確認暫停點（Identifying stoop point）

- 健康/休息（Health/Rest）
- 重要工作之排序（Task prioritization/organization）
- 發現預期問題（Finding/expecting problems）
- 狀況警覺（Situation awareness）

- 航空事故之次要因素：
  - 工具管理/時程安排/品質管制
  - 檢查卡說明/指示不明確
  - 維修人力不足
  - 檢查員/督導不在場
  - 工作超時
  - 緊張/家庭問題/使命必達心態
  - 疲勞
  - 買單不確實
  - 時間不足，造成簡化標準程序，走捷徑
  - 工作步驟繁，複造成簡化標準程序，走捷徑
- 領班/督導之過失
  - 錯用人力使其執行之作業難度超過本身能力
  - 工作步調超過派用人之能力
  - 人力不足

■ 訓練不足

■ 領班未能授權下屬，形成督導不周之氛圍

■ 領班未能獲得下屬之信賴

■ 未能使下屬有足夠休息

■ 例行違規

➢ 組織程序之制訂

■ 顯性失效及隱性失效皆源自於組織程序，例如政策制定，目標訂定，操作、訓練、維修之安全管理，資源分配，計畫與時程，激勵與支持，控制，檢察，報告等。（詳圖 3-24）

■ 個人因素亦受組織程序缺失之影響，以致使其失去動力，疲勞與緊張，時間壓力，對危害之錯誤認知，技術不足等。

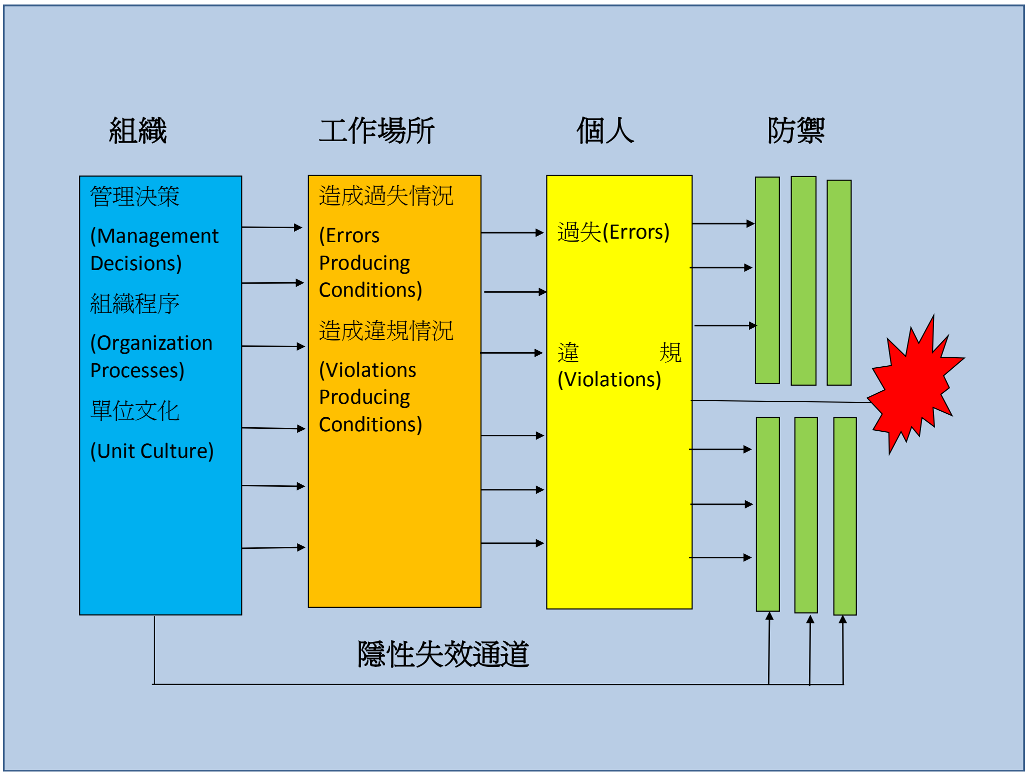


圖 3-24 顯性失效及隱性失效皆源自於組織程序

- 當人們執行維修工作，所發生的錯誤皆爲眾所預期時，許多維修機構都在嘗試著改變人因狀況。
- 構成一個組織安全文化的兩個元素：
  - 僱員必須明白他的行爲將被組織依賴，亦將被公正對待
  - 懲處政策無法解決出發點爲善意但發生不良結果之人爲過失
- 人們須被鼓勵共同經營一個相互信賴的氣氛，甚至對提供安全資訊者施以獎勵
- 但是，對於可接受與不可接受之行爲，須有一明確界線
- 公平正義文化（just culture）
  - 信賴的文化（A trust culture）
  - 完全處罰對照不責備（Wholly punitive versus blame-free）
  - 自然本性將於疏失與違規之間劃出界線（Natural instinct is to draw the line between errors and violations.）
  - 勿只將紀律使用在有不好結果發生時（Do not decide discipline only the event outcome.）
  - 紀律如使用得宜，將使不可接受之行爲發生頻率降低（Discipline, when used fairly, will reduce unacceptable behavior.）
- 組織要如何作方能經營出一個適宜的安全文化？
  - 結構，執行，管理與政策：具體與客觀（Structures, Practice, Control & Policy: Concrete & objective）
    - 技術資料之運用（use of tech data）

- ◆ 走捷徑之默許（Allowing shortcut）
- ◆ 品保之角色（Role of QA）
- ◆ 壓力（Pressure）
- ◆ 天氣限制：風力、氣溫等（Wx restrictions: wind, temperature, etc,）

■ 信念，態度，價值，道德，言而無信：抽象與主觀（beliefs, Attitudes, Values, ethics, often unspoken: abstract & subjective）：

- ◆ 生命/安全（Life/Security）
- ◆ 做好工作（Job well done）
- ◆ 認知（Recognition）
- ◆ 公平（Fairness）
- ◆ 責備文化（Culture of blame）

➢ 組織內積非成是（Norms）的文化

■ 非正式或未見於法規，但卻爲團隊所接受的作業方式。

■ 正面的 Norms 文化，將對組織產生正面的影響，例如：請你再確認一下你的工作是否正確。

■ 負面的 Norms 文化，將對組織產生負面的影響，並有發生過失的潛在風險，例如：依據自己的記憶來執行工作，而未依據工單或手冊。

➢ 如何看待 Norms

■ 尋找在生活上及工作上所發生的 Norms。

■ 將正面的 Norms 從負面的 Norms 中指認出來

- ■ 強調正面的 Norms，消除負面的 Norms。
- ■ 研究探討它們（Norms）並發揮個人在團隊的影響力，來消除負面的 Norms。

➢ 決策下達（Decision Making）

- ■ 決策下達雖在人腦的作業只是一瞬間，但其實是經過一套程序的。人們會先蒐集資料，這些資料有部分是以前的經驗所儲存下的，經過一個分析的程序過濾所有資料，最後一句結果做出決策，決策既定即進行行動，行動完畢在繼續搜及後續資料，如此周而復始。（詳圖 3-25）

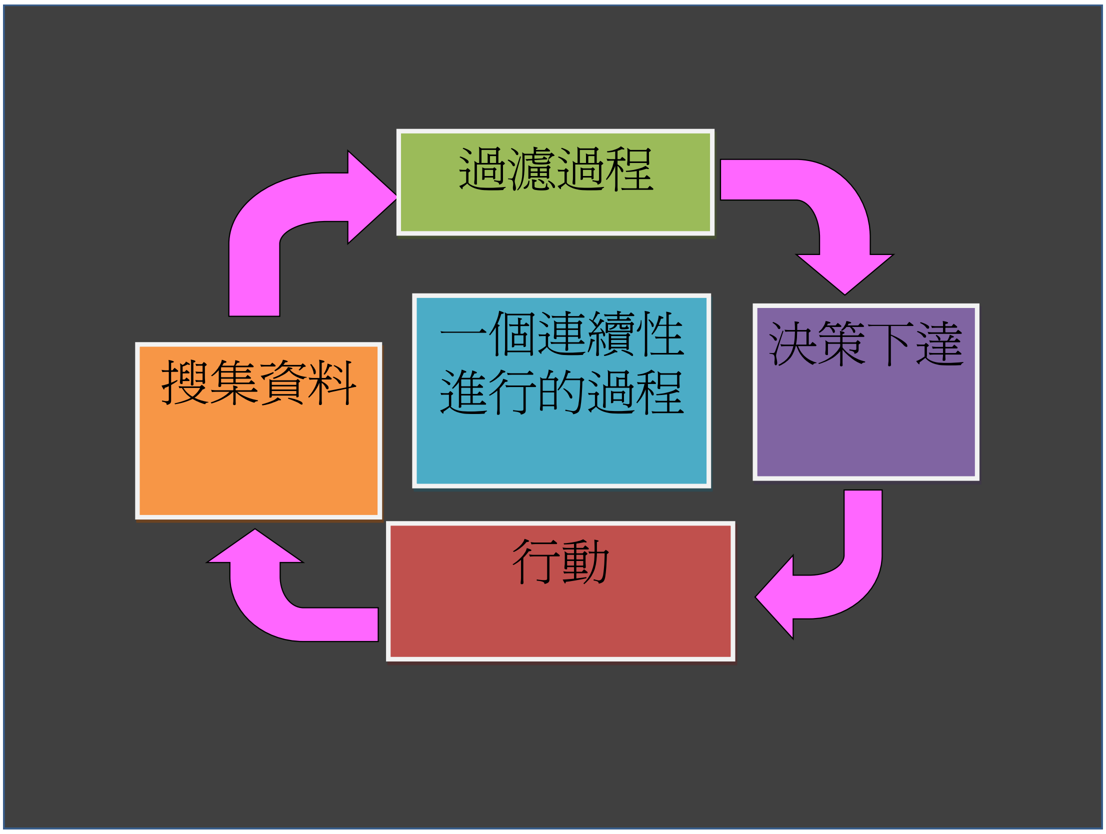


圖 3-25 決策下達程序

➢ 決策下達時易發生之過失

- ■ 過度自信

- 過度依賴最近經驗所得之資料
- 自滿大意
- 選用最顯著線索，例如，最響的聲音，最亮的光線等。
- 道德標準
- 感覺
- 危機管理不足

➢ 道德：法規或標準是爲專業人群行爲的調理

- 個人：機械員
- 組織：維修機構

➢ 決策下達之定義：基於可用的資訊，運用邏輯及合理的判斷，選擇行爲準則的能力。

➢ 決策下達之訓練

- 於壓力環境下，人們下意識的總會回到他們記憶中最熟悉的事物
- 學習過濾並留取適當的感覺性輸入
- 清楚自我的極限，並於極限範圍內操作
- 避免故步自封
- 避免自大意滿
- 察覺不對立即停止

➢ 操作上的風險管理（Operational Risk Management, ORM）

- 風險是一個可能致使傷害或損失的機會

- 風險管理是一個指出危機，評估其意涵，下達行動方向的決策及平價結果的一個過程。

➢ ORM 的好處

- 減少災難，事故，意外
- 降低人員傷亡，財物及其他成本的損失
- 增進訓練的現實性及其效果
- 增進任務或操作的能量

➢ 操作上的風險管理（Operational Risk Management, ORM）（詳圖 3-26）

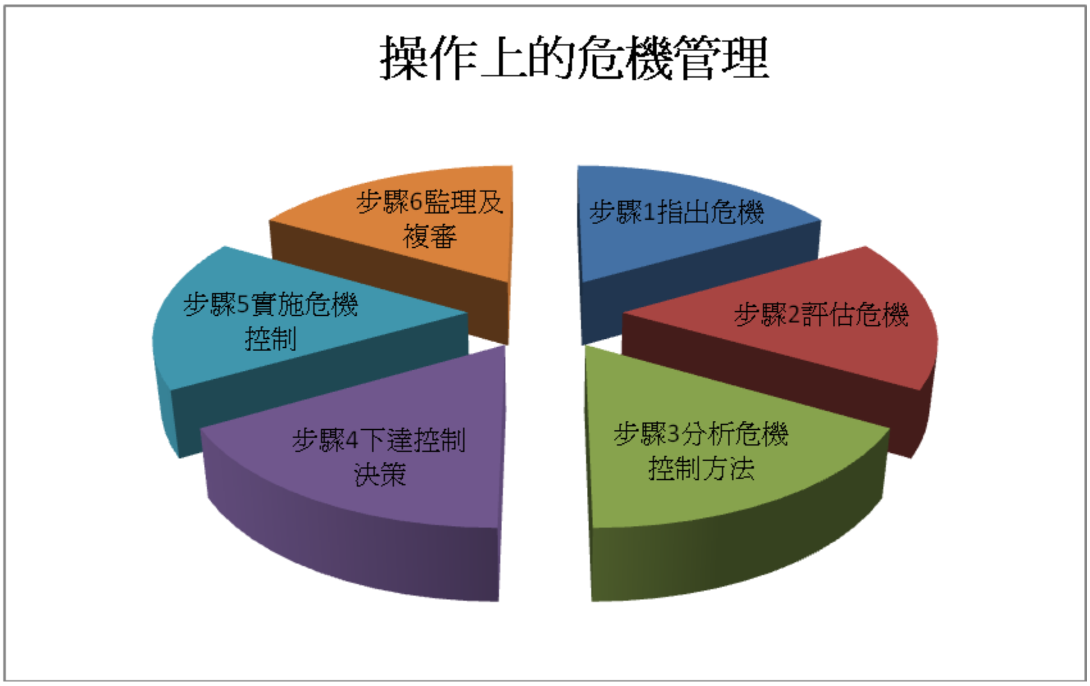


圖 3-26 操作上的風險管理（Operational Risk Management, ORM）

➢ 風險評估：基於其事件之嚴重性及損失的可能性，來認定風險程度

➢ 災害之嚴重性（Mishap Severity）`：預期事件後果

一級，災難性的（Catastrophic）：任務徹底失敗，人員死亡或系統喪失

三級，中等的（Moderate）：未嚴重衝擊任務，人員受傷或系統變異

四級，無緊要的（Negligible）：微弱衝擊任務，人員受傷或系統受損

二級，危急的（Critical）：嚴重衝擊任務，人員嚴重傷害或主要系統受損

- 災難發生的可能性（Mishap Probability）　（詳圖 3-27,28,29）
  - A：經常性（Frequent - Occurs often）
  - B：很有可能發生（Likely - Occurs several times）
  - C：偶而發生（Occasional – Will occur）
  - D：難得發生（Seldom – Could occur）
  - E：不太可能發生（Unlikely – Very rarely or will not occur）

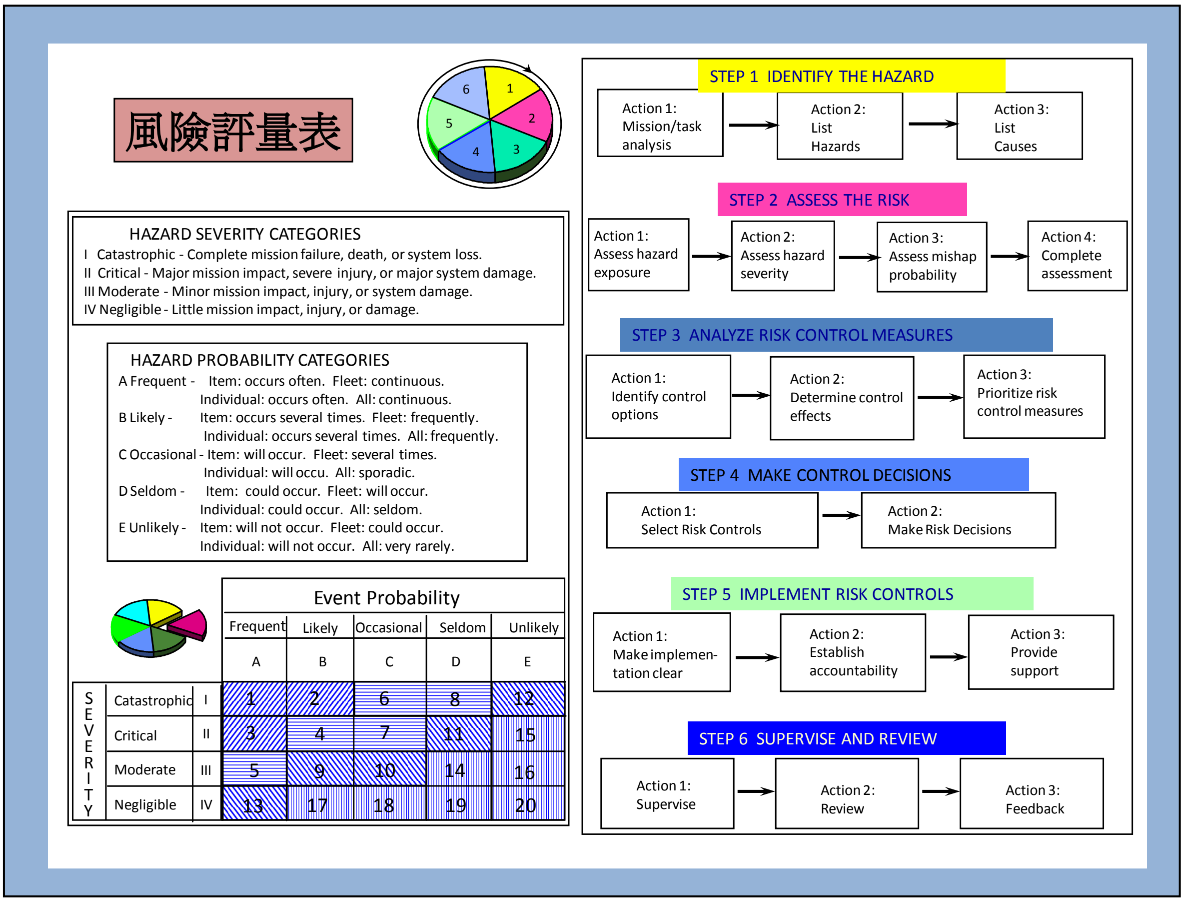


圖 3-27 風險評量表

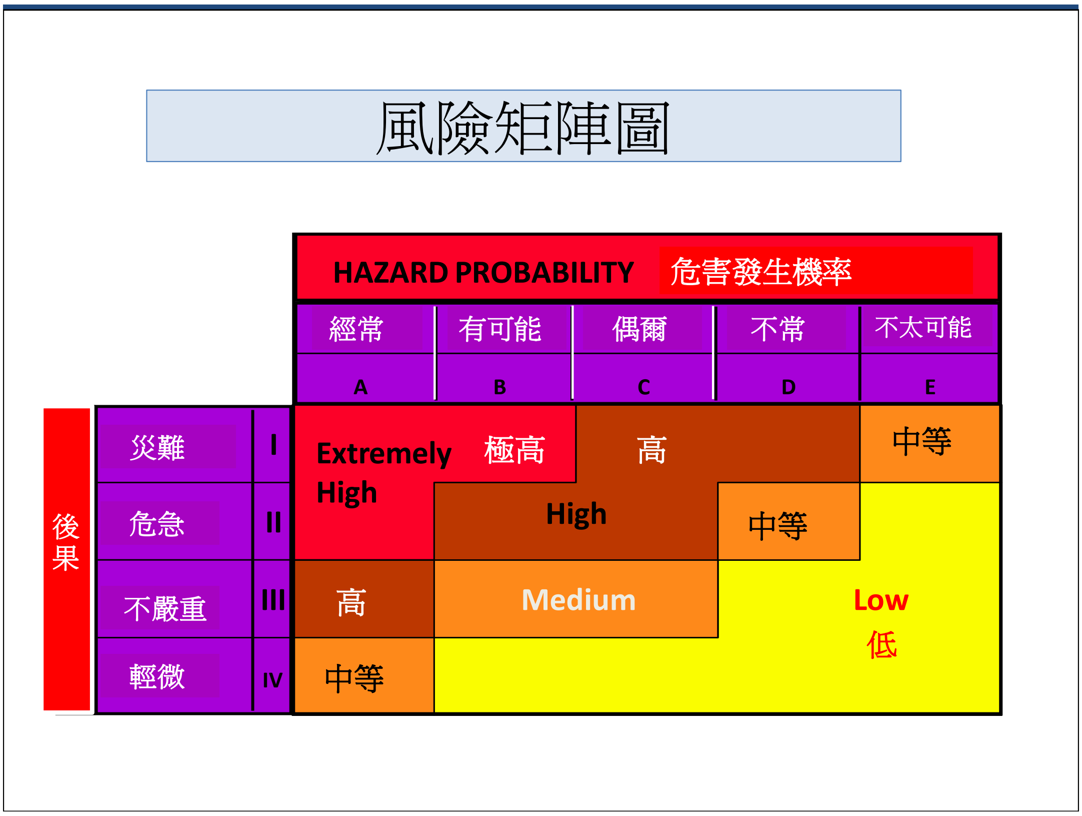


圖 3-28 風險矩陣圖

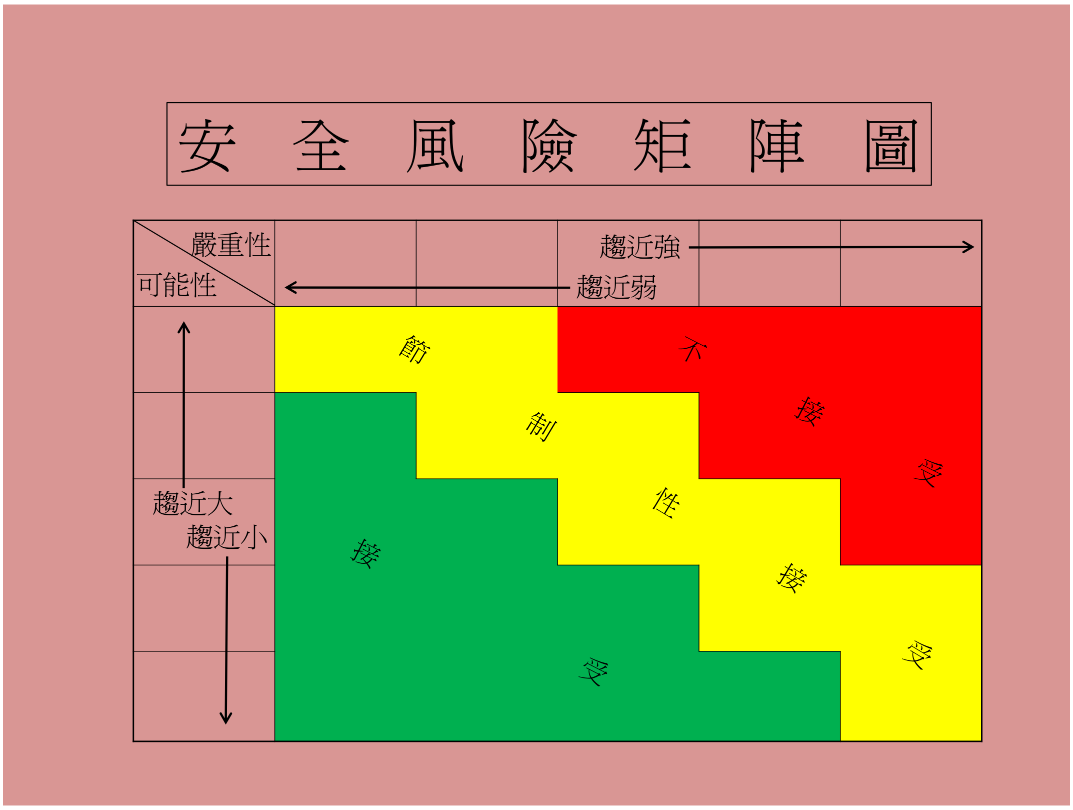


圖 3-29 安全風險矩陣圖

壓力與疲勞

- 壓力（Pressure）=緊張（Stress）
  - 緊張的徵狀或訊號
    - 身體的（Physical）
    - 認知的（Cognitive）
    - 情緒的（Emotional）
    - 行爲的（Behavior）
  - 是造成不良決策下達的首要因素之一
  - 未能舒緩的緊張所造成的疲勞是眾所周知的
- 疲勞
  - 是造成不良決策下達的首要因素之一
  - 是一種倦怠的感覺，使人無法集中精神於工作上
  - 源於夜間失眠或白天的崩潰致使表現低落
  - 以一個維修員來說，通常都會低估了問題的嚴重性，反而高估了與其相處的能力
- 疲勞如何造成
  - 缺少睡眠或睡眠品質低落
  - 非傳統之工作模式

- 空氣溫度
- 噪音指數
- 抽菸
- 個人因素（節食）
- 緊張
- 熬夜

➢ 如果個人執行飛機維修作業時間長達：

- 18 小時，則血液之酒精含量（Blood Alcohol Concentration, BAC）達 0.05%
- 24 小時，則血液之酒精含量（Blood Alcohol Concentration, BAC）達 0.10%
  - ◆ 判斷力衰退
  - ◆ 反應力降低
  - ◆ 遺忘例行作業
  - ◆ 問題解決低落

➢ 睡眠的需求

- 一般人須要平均 7-9 小時睡眠
- 每日 5 小時的睡眠最多不超過連續的 14 天
- 睡眠不足所產生的疲勞是會累積的
- 睡眠債務無法預先儲存

➢ 正常睡眠的週期

利用 Electroencephalogram（EEG） 測量腦波而在 EEG 中，研究者發現睡眠中有四種明顯的階段 Stage1，Stage2，Stage3，Stage 4 及 REM 睡眠。爲何 REM 不在四種階段中呢？因爲在清醒經過 Stage1 到 Stage4 時，腦波會越來越緩慢，而從 Stage4 會直接到 REM 階段，但是 REM 階段時的腦波就和清醒時沒太大差別（這時人仍然熟睡），如果將人在這時候搖醒他，有 80%的人都說他正在作夢。爲何稱爲快速眼動睡眠？因爲除了 EEG 之外，還有 EOG 以及 EMG 可測量睡眠，其中利用眼睛運動測量的工具，在 EEG 偵測到進入 REM 睡眠時，眼睛的運動也同時增加，所以 REM Sleep 又稱快速眼動睡眠。（詳圖 3-30）

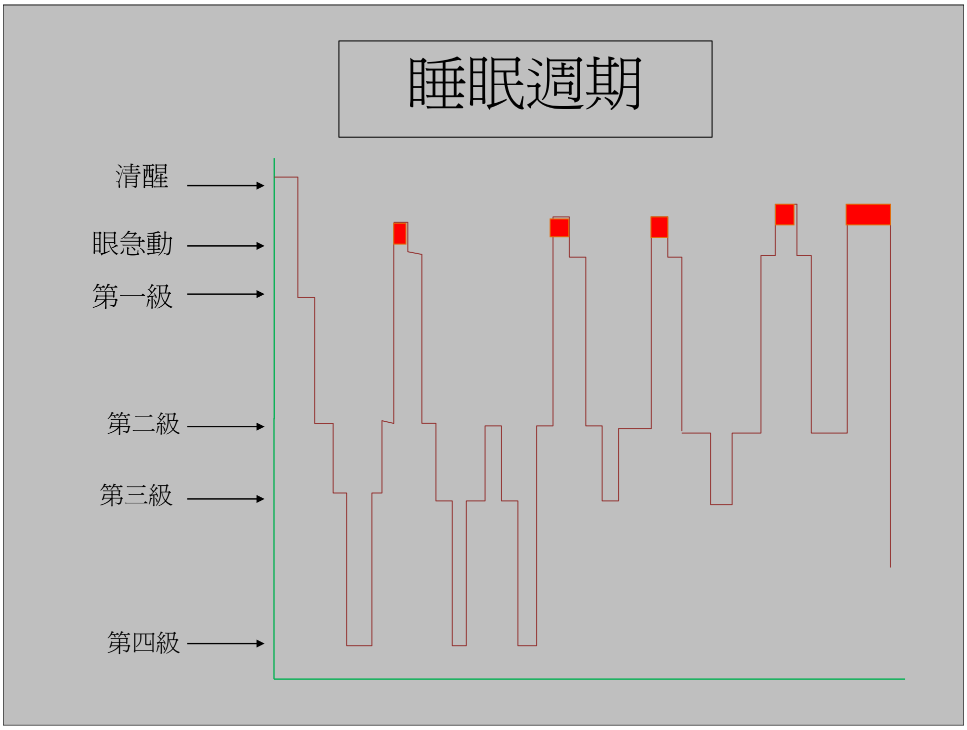


圖 3-30 REM Sleep

➢ 酗酒睡眠的週期

酗酒後的睡眠則因酒精在體內的作用，影響了腦部的正常運作，研究者發現睡眠中不經過 Stage1 , Stage2 , Stage3, Stage 4 等四種明顯的階段及 REM Sleep，而是直

接進入第四級。如此睡眠模式失去身體復原，荷爾蒙的製造期及肌肉組織的修護，所以酗酒醒來後會覺得疲憊倦怠。（詳圖 3-31）

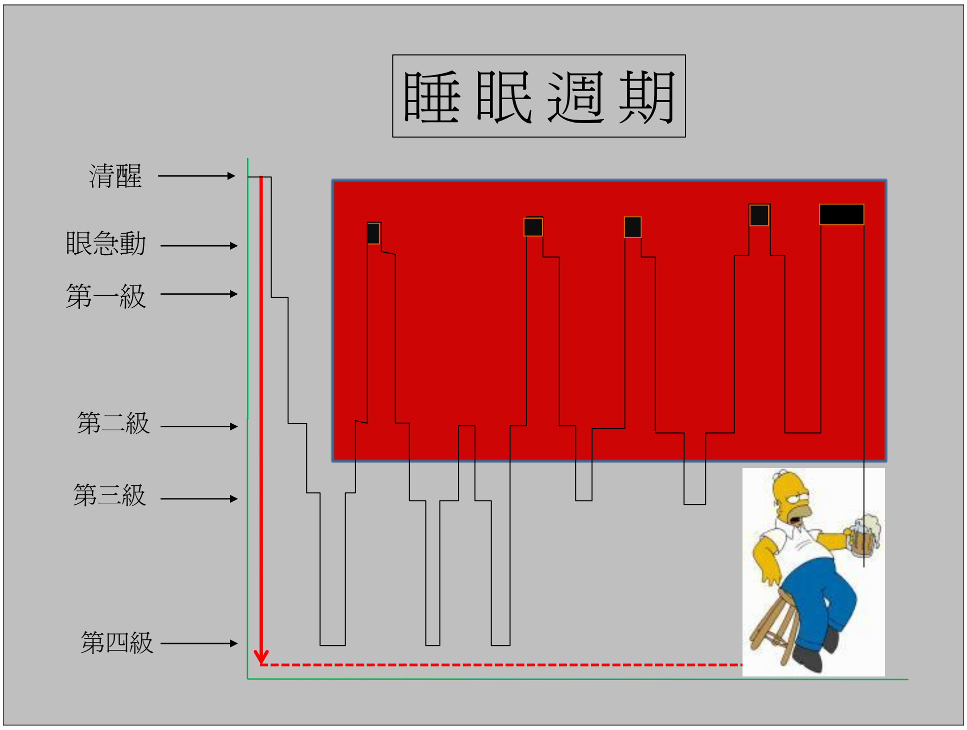


圖 3-31 酗酒醒來後會覺得疲憊倦怠

➢ 睡眠生理學

- 非眼急動睡眠（Non Rapid Eye Movement Sleep）
    - 第一級與第二級
    - 第三級與第四級
    - 身體恢復（Physical restoration）
    - 產生荷爾蒙 （Hormone Production）
    - 組織修復（Tissue Repair）
- 眼急動睡眠（Rapid Eye Movement Sleep）
    - 作夢（Dream）

- ◆ 肌肉痙攣（Muscle Twitching）
- ◆ 眼睛急速轉動（Rapid Eye Movement）
- ◆ 解決問題（Problem Solving）
- ◆ 長短期記憶（Short-to long-term Memory）

■ 行動對策（Operational Countermeasures）

- ◆ 找人對話（Conversation）
- ◆ 身體活動（Physical Activities, Writing, eating, exercise, brush teeth, wash face）
- ◆ 伸展運動（Stretching）
- ◆ 日光浴（Light Exposure）
- ◆ 吃點心（Snack on food）
- ◆ 喝咖啡因（Caffeine）

■ 矯正不良睡眠（Fix）

- ◆ 睡眠紀律 （Sleep Discipline） （儘量避免睡眠債）（Minimize sleep debt）
- ◆ 經營友善睡眠環境（Sleep Environment）
- ◆ 運動（Exercise）
- ◆ 壓力管理（Managing your stress）
- ◆ 光線（陽光/環境） （Sun shine/ Lighting）

➢ 溝通（Communication）

■ 資源管理，例如領導統御、決策下達、危機處理、緊張管理等，皆爲人與人間之互動，須透過相互溝通，使對方完全瞭解我方之目的，方能稱之有效溝通，溝通實爲資源管理之基礎。（詳圖 3-32）

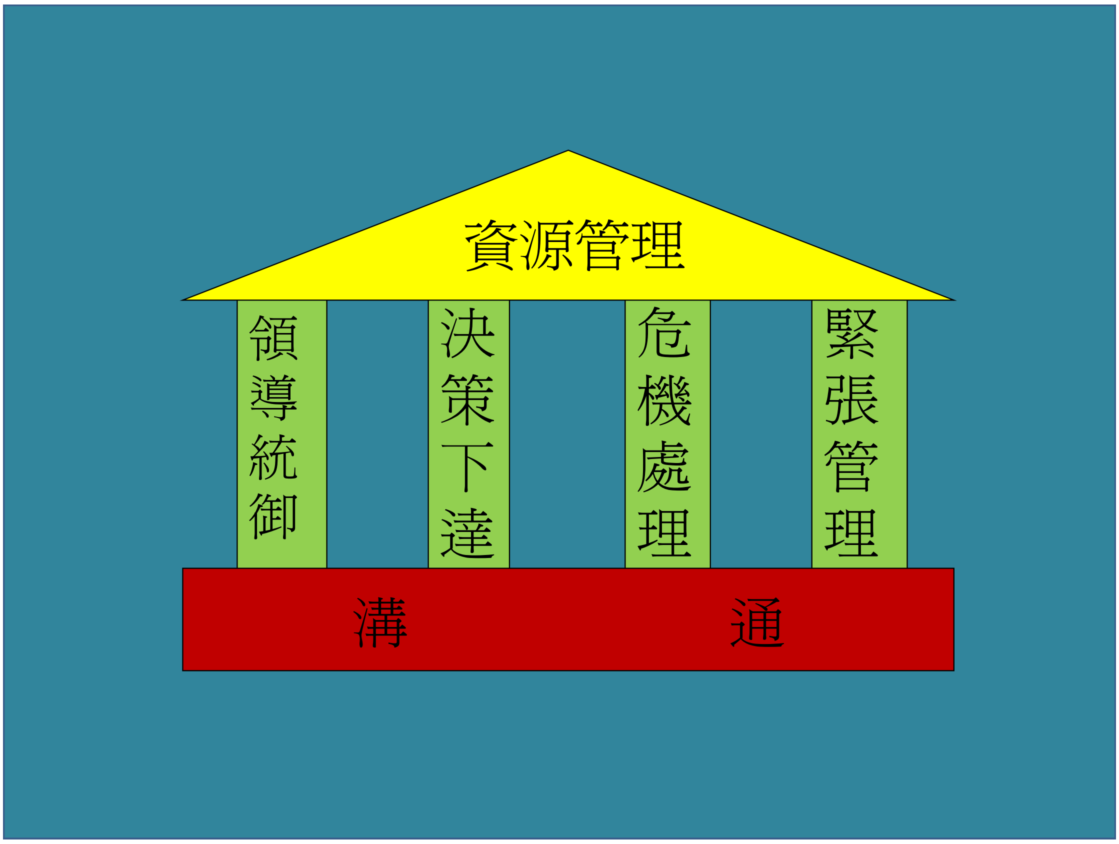


圖 3-32 溝通實爲資源管理之基礎

■ 溝通即是一個團隊內之組員間進行精確有效的資訊交換。

■ 溝通的方法

專家實驗證實人與人溝通的方法，語言雖最爲普遍，但如無音調變化其實能讓對方了解的並不多，只有 7%的內容能讓對方瞭解，如加上音調的變化，抑揚頓挫的語音能使對方對說話者的內容增加到 38%，如再加上一些行爲語言，如比手勢，做動作等，即可讓對方對我說話之內容達到 100%之瞭解，亦即行爲語言的溝通效率爲 55%，是故與人溝通時應注意溝通的方法以達有效

溝通。（詳圖 3-33）

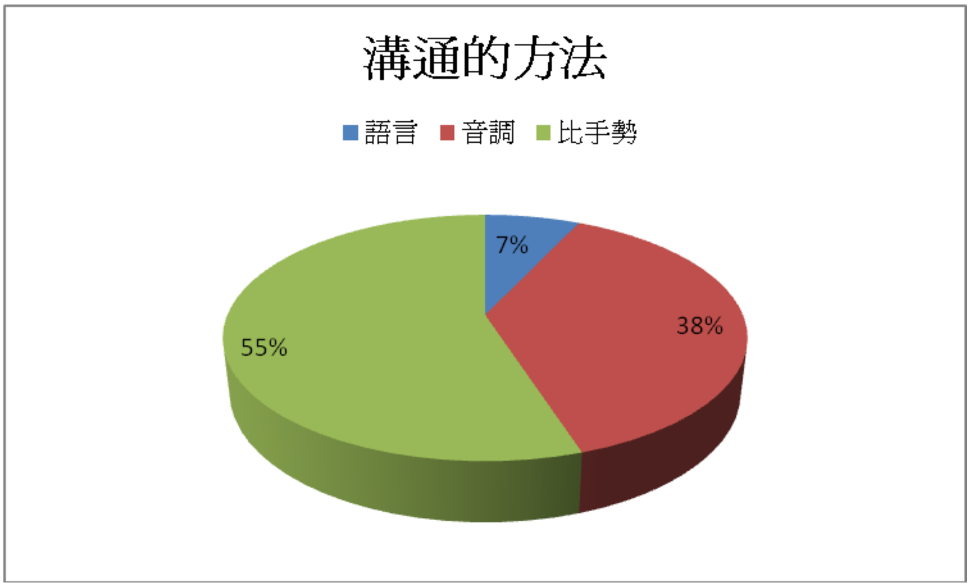


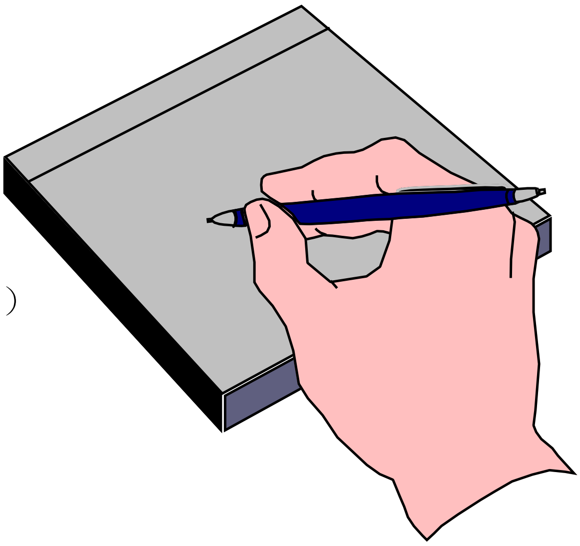
圖 3-33 溝通時應注意溝通的方法以達有效溝通

- 關鍵時刻的溝通
  - 交接班時刻
  - 維修廠站更換時刻
  - 問題解決/故障排除
    - 個人/組員間
  - 紀錄登錄
    - 維修作業之電腦
    - 維修作業之紀錄簿
  - 危害狀況處理程序或料材之使用
    - 維修業務之運轉

- 非破壞性 X 光檢查

- 手寫式溝通
  - 最爲困難，回饋受限，無音調及身體語言。
  - 讀者無法提問
  - 爲何顧慮手寫式溝通
    - 維修紀錄簿之登錄模糊，不明確，不完整，如，修護資料登錄、簽證等，皆可能造成事故

- 溝通之障礙
  - 偏見（Prejudice/bias）
  - 噪音光害（Noise/lighting）
  - 分散注意力的事物（Distraction）
  - 組織文化（Culture）
  - 語言（Language）



- 溝通之障礙物
  - 位階/資歷差異（Deference to rank/experience）
  - 專業性的尊重（Professional Courtesy）
  - 自滿自大（Complacency）
  - 怕樹敵（Fear of animosity）
  - 懼強勢（Intimidation）

- 使命必達（Missonitis）
- 工作量（不足/過量）Workload （over and under）

■ 改善溝通

- 改用易懂字句或言詞表達（paraphrase）
- 提問（Ask questions）
- 眼神接觸（Make eye contact）
- 使用正面之身體語言（Use body language）
- 注意排除溝通之障礙及障礙物，不論是本身或他們（Watch for filter, theirs or yours）
- 聆聽：先求瞭解再看是否瞭解

■ 自信與魄力（Assertiveness）

- 表達自我感受、意見、信念與需求的能力
- 在正面及有效的態度下表達自我的能力

■ 何時當表現自信與魄力

- 遭遇問題
- 有了答案
- 不清楚狀況

■ 如何表現自信與魄力

- 專注
- 說出顧慮

- ◆ 說出問題
- ◆ 說出解決方法
- ◆ 意見一致時

■ 因爲維修作業可能肇致生命財產的危害，個人於發現或感覺到危險時，需要一個暫停或終止作業的方法

■ 當領班專注於維修作業時，其下屬人員最好能夠評估危險，太依賴領班的經驗或判斷，而保持沉默，往往失去一個中斷災難鍊的機會

■ 操作人應於其組織使用有聲口語，任何人於發覺有危害可能或情況有異狀況，立刻出聲停止作業，待狀況排除後再行動工

➢ 人因之應用（詳圖 3-34）

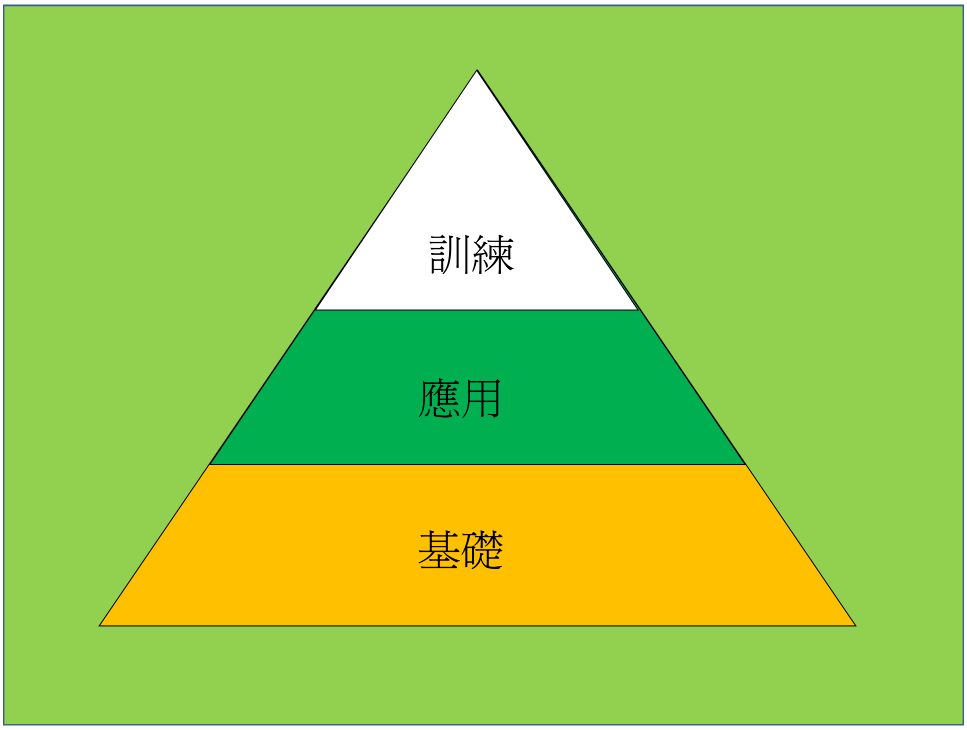


圖 3-34 人因之應用

■ 系統模組

■ PEAR 之應用

■ 團隊

■ 事件調查

➢ 雷氏瑞士乳酪模組（Reason’s Swiss Cheese Model）

每片乳酪中的一個洞孔代表一項隱性缺失，當個人身體狀況不穩定時時，當時又有不安全環境誘發不安全行爲，加上不當督導及不健全德組織文化，如此數片乳酪的洞孔剛好重疊時，就是顯性事件鑄成的時機。

■ 隱性狀況：組織的政策不周延或經理人的督導與管理權責不清、法規，標準作業及操作手冊規範不詳實，工作環境不友善等問題之存在，平時不易發現

■ 顯性失效：維修人員執行維修作業之行爲與態度不符標準，加上前述之隱性狀況，即導致飛安事件的發生（詳圖 3-35）。

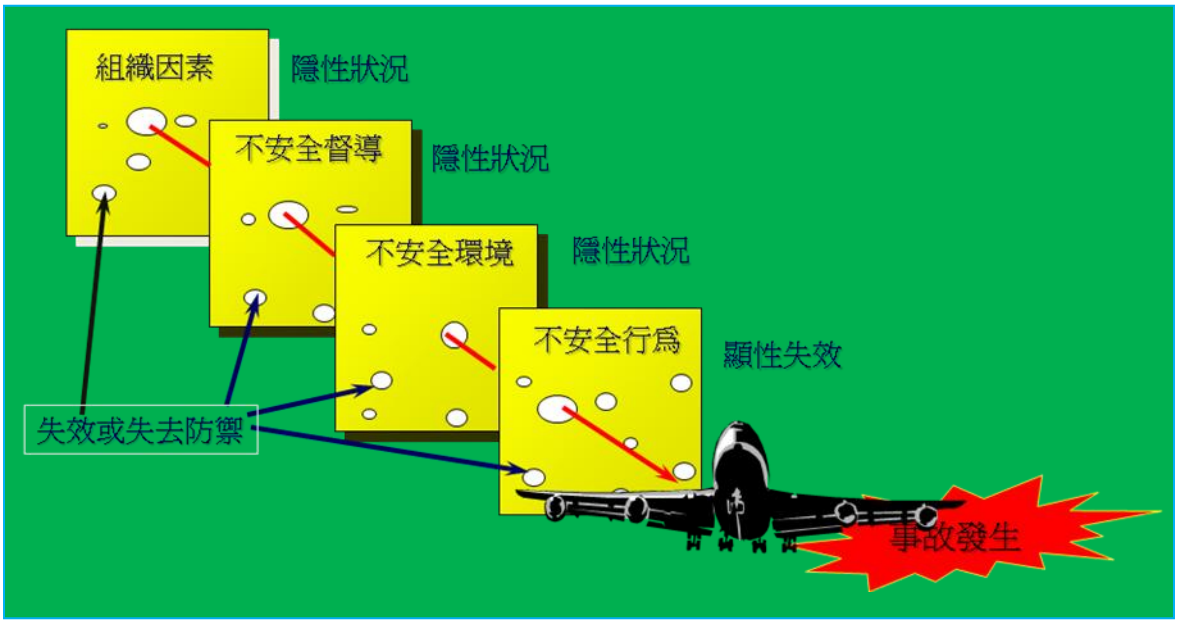


圖 3-35 維修人員執行維修作業之行爲與態度不符標準，加上前述之隱性狀況，即導致飛安事件的發生

每一片乳酪中代表一項防禦機制，每一項防禦機制如果運作得宜，即可防止

一個錯誤鍊（Error Chain）的發生，每一片乳酪當有許多孔洞，表示每項防禦機制都有某些缺陷，當這些乳酪上的某一個孔湊巧都連成一線對上時，表示這些防禦機制中的某銷缺陷已形成一條錯誤鍊，事故發生以不能避免。防禦機制內容簡述如下：

- 不安全行爲
  - 決策（判斷）的錯誤
  - 技術（操作）的錯誤
  - 知覺（感官）的錯誤
  - 違規（例行、特殊）的錯誤
- 不安全操作的前置狀況
  - 不佳的心智狀態
  - 不佳的生理狀態
  - 生理的心智的極限
  - 組員資源管理
  - 個人的準備狀況
  - 自然的環境
  - 技術的環境
- 不安全的督導
  - 不充分的督導
  - 未計畫周詳之維修任務

◆ 未能修正已知問題

◆ 違規的督導

■ 組織（管理）之影響 （詳圖 3-36）

◆ 資源管理

◆ 組織文化

◆ 組織的運作

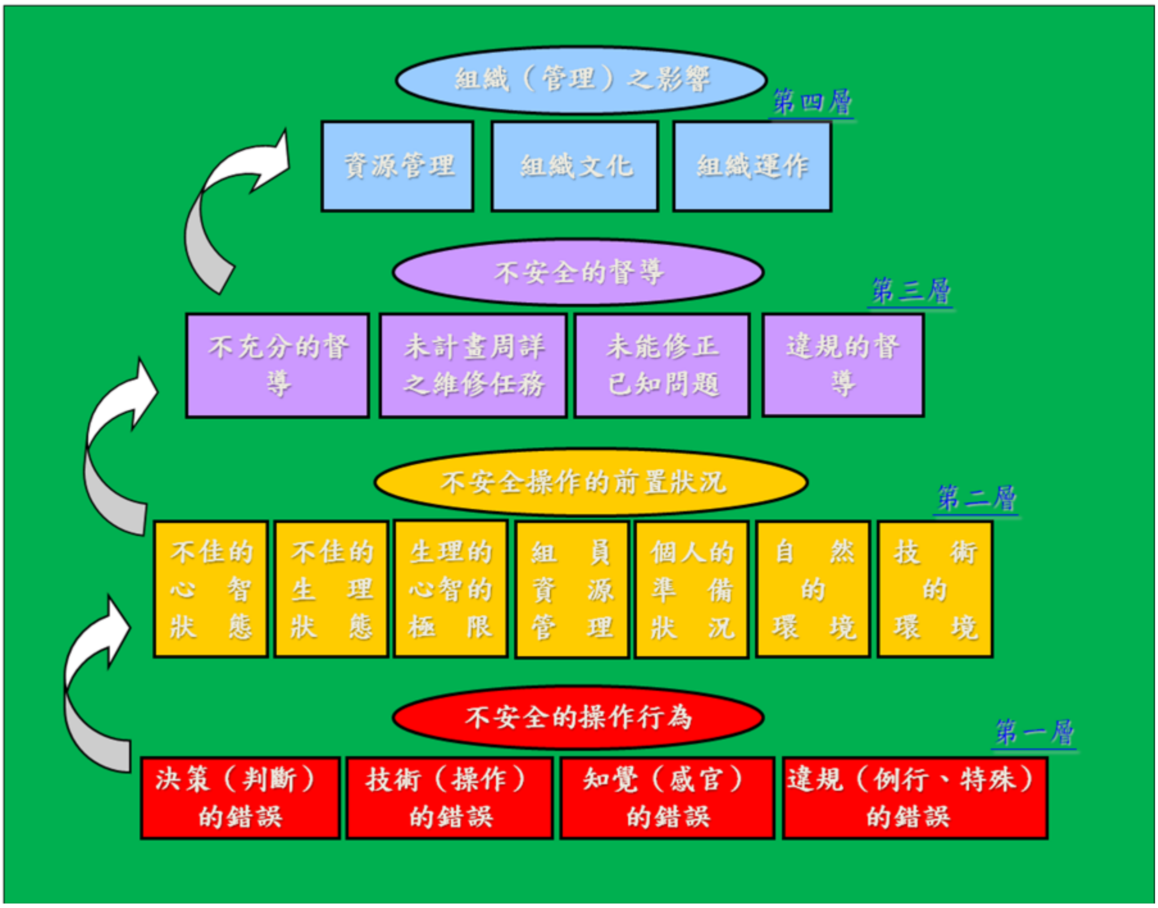


圖 3-36 組織（管理）之影響

➢ 人因模組

■ 使用於人因分析的工具，目前廣爲人知的有 SHELL 及 PEAR 兩種模組

◆ SHELL 模組：中間 L 的被 SHEL 所圍繞，其相鄰兩者產生互動。（詳

圖 3-37）

圖 3-37 SHELL 模組

- L（Liveware）中間的 L 代表個人
  - 人體身、心理的狀況，如
  - 緊張
  - 壓力
  - 疲勞
  - 分心
- S（Software）代表軟體：中間的個人和下列軟體間之互動分析
  - 程序（Procedures）
  - 政策法規（Policies / Rules）
  - 手冊（Manuals）

- 標籤（Placards）
- 所有資訊（Documents）

- H（Hardware）代表硬體：中間的個人和下列硬體間之互動分析
  - 工具
  - 裝備
  - 設施
  - 所有飛機維修相關之物質
- E（Environment）代表環境：中間的個人和下列環境間之互動分析
  - 空調
  - 噪音
  - 照明
  - 氛圍：工作量大/壓力、工作難度高/緊張
  - 飛機維修場所周遭之環境
- L（Liveware）外邊的 L 代表人群：中間的個人和外邊人群間之互動分析

◆ PEAR 模組（詳圖 3-38）

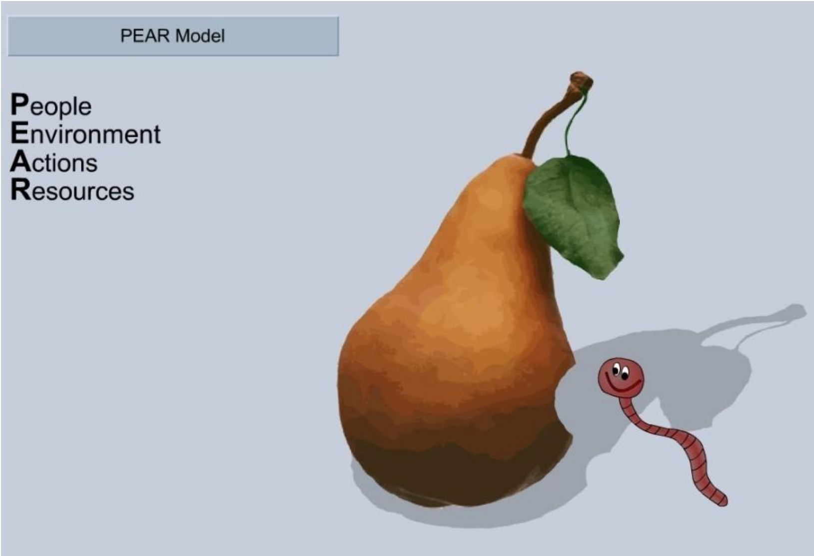


圖 3-38 PEAR 模組

- Pear 爲梨子之意，取其名之用意爲便於記憶
- P（People）代表執行飛機維修工作的個人身體的狀況
  - **身體（Physical ）**
    - 體型大小（Size）
    - 性別男女（Gender）
    - 年齡老幼（Age）
    - 力量強弱（Strength）
    - 視覺、嗅覺、味覺、聽覺、觸覺五官的敏感度（The five senses ）
  - **生理（Physiological ）**
    - 健康情形（Health）
    - 營養情況（Nutrition）

- 生活方式（Lifestyle）
- 警覺性/疲勞（Alertness/fatigue）
- 化學藥品的依賴性（Chemical dependency ）

■ **心理（Psychological）**

- 經驗多寡（Experience）
- 知識深淺（Knowledge）
- 訓練有無（Training）
- 態度積極或消極（Attitude）
- 情緒輕鬆或緊張（Emotional state ）

■ **身心理狀況（Psychosocial ）**

- 人際關係（Interpersonal relations）
- 溝通能力（Ability to communicate）
- 同情心（Empathy）
- 領導能力（Leadership）

● E（Environment）組織與環境

■ **物質性的（Physical）**

- 極端天氣（Weather extremes）
- 維修場所戶內戶外（Location （in/out） ）
- 工作空間（Workspace）

- 照明（Lighting）
- 聲音大小（Sound levels）
- 後勤（Housekeeping）
- 安全議題（Safety issues）

■ **組織性的（Organizational ）**

- 員工（Personnel）
- 督導（Supervision）
- 勞工管理（Labor – management）
- 公司規模（Size of company）
- 收益性（Profitability）
- 工作保障性（Job security）
- 品德（Morale）
- 企業文化（Corporate culture）
- 安全文化（Safety culture）

● A（Actions）執行飛機維修工作之行動及作爲

■ 需要知識（What do you need to know?）

■ 須具備技術（What skills are necessary?）

■ 工作步驟（Steps to perform a task）

■ 動作順序（Sequence of actions）

- 溝通需要（Communication requirements）
- 資訊需要（Information requirements）
- 檢察需要（Inspection requirements）
- 認證需要（Certification requirements）

● R（Resources）工具、程序等支援飛機維修作業之資源

- 技術資料系統（Technical documentation systems）（詳圖 3-39）

圖 3-39 技術資料系統（Technical documentation systems）

- 測試裝備（Test equipment）（詳圖 3-40）

現代安全實務考量一旦發生意外及疏失時，能立刻警覺並指出即排除安全威

圖 3-40 測試裝備（Test equipment）

- ■ 充裕時間（Enough time）
- ■ 充足人力（Enough people）
- ■ 升高機具，梯架，座椅（Lifts, ladders, stands, seats）
- ■ 料材（Materials）
- ■ 手電筒（Portable lighting, heating, cooling）
- ■ 訓練（Training）

■ 事件調查

現代安全實務考量一旦發生意外及疏失時，能立刻警覺並指出即排除安全威脅。

➢ 過程中的基本假定 Basic Assumptions

■ 在狀況發生前必須要有警覺心

■ 經過 HFAM 訓練後發展一套警覺文化，將可增強我們的視野

■ 我們如不能發覺問題，我們就不可能排除問題，那問題就永遠存在，直到發生事故

■ 只要問題被發現，就可說問題已解決一半了

➢ 發展訓練（詳圖 3-41）

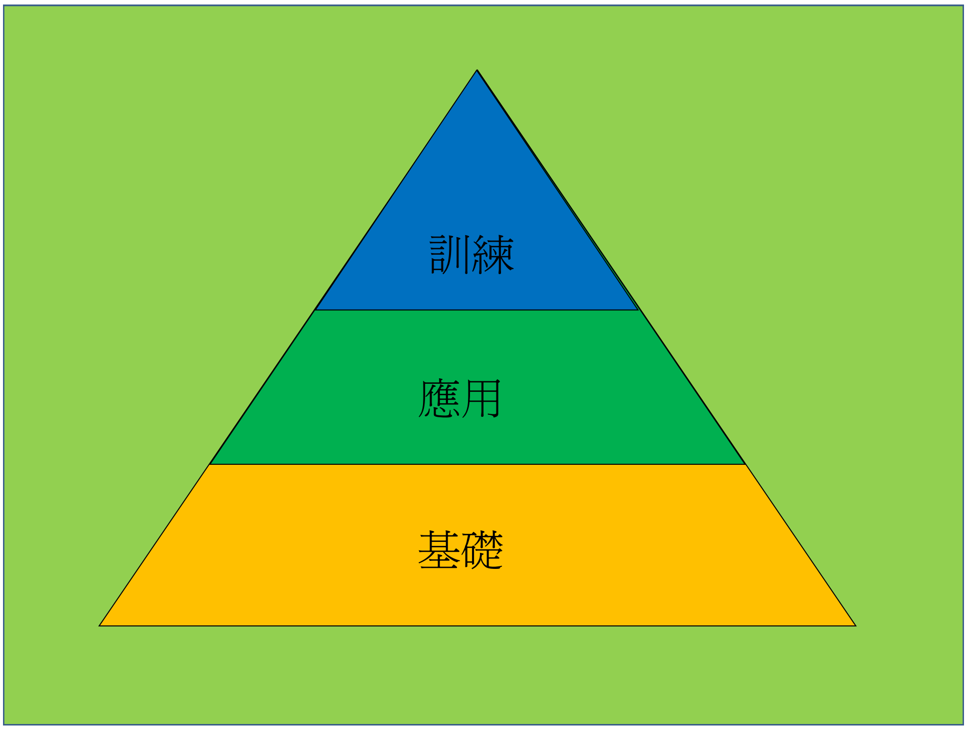


圖 3-41 發展訓練

■ 評估

- 事件調查
- 鷹湖研討
- 建立人因訓練課程

- 評估人因訓練課程

- 事件調查之目的
  - 調查由機械員或檢查員所造成之事件，以達危機管理之目的
  - 幫助組織指出並瞭解人為過失及偏離程序之多重肇事因素
  - 掌握這些肇事因素，減低將來類似事件之發生
- 如何進行事件調查
  - 指定一專責部門來負責調查作業之執行
  - 勞工、經理人及監理機關間之努力合作
  - 訂定調查程序
  - 制訂政策及步驟
  - 如有必要，實施公正文化之紀律政策
- 幾近事件（Near Events）之重要性
  - 幾近事件的發生顯示某些影響安全系統的因素
  - 為重大意外或事故之徵兆
  - 減低幾近事件的件數，亦將減少產生重大意外及事故之機會

➢ 鷹湖事件研討（Eagle Lake Case Study）

- 調查報告摘錄

1991年9月11日，約1003中部日光時間，大陸快遞航空公司所屬，2547班機，安布雷爾120型機，按美國聯邦法規14號135部之規定，執行民航運輸載課業務時，發生空中飛機結構解體而墜毀在德州鷹湖附近之玉米田中。2位飛行組員1位空服員及11位乘客於事故中罹難。

美國運輸安全委員會認爲可能肇事之主要原因爲，大陸快捷公司之機械員及檢查員，未能確實遵守飛機水平尾翼除冰靴安裝之正確品保程序，使左側水平尾翼前緣於飛行中脫離固定位置，造成飛機立即改變成俯角姿態，致使飛機解體。可能肇事之次要因素爲，大陸快捷公司之管理，未能確實遵守，核准之維修程序，美國聯邦民航主管官署未能發現及確認所轄未遵照核准程序施工。

該調查重點在於：

美國聯邦民航主管官署、飛機製造廠及飛機操作人之責任是決定飛機系統中關鍵性的項目及檢查的層次。

交接班人員及維修輪班交接資訊的標準程序。

調查結果，安全局發布飛安改善建議給美國聯邦民航主管官署，發展告知飛行組員最近飛機維修工作之可行方法，並審核法規政策及實務來建立一套須要檢查項項目（RII），尤其針對類似項目。同時依據1992年2月28日之調查結果，運安會提出飛安改善建議給美國聯邦民航主管官署，加強大陸快捷公司之飛航標準查核及飛航標準程序指導，包括國家民航安全檢查程序。（該調查報告詳附錄）

- 研讀事實資料 1.5.3；1.13.2；1.17.1 到結束
- 分成討論小組
- 討論主題與程序如下（詳圖 3-42）
    - 甚麼是不安全行爲（unsafe acts）
    - 甚麼是過失醞釀狀況（error producing condition）
    - 爲什麼有防禦機制卻無效
    - 製作導致事故之過失鍊

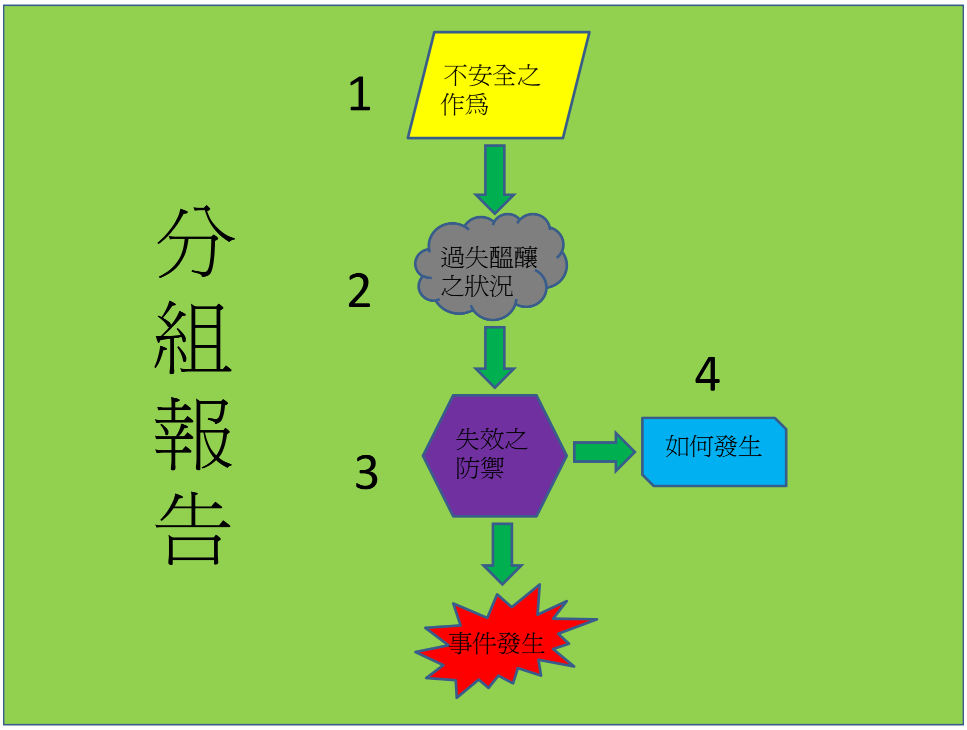


圖 3-42 討論主題與程序

■ 甚麼是不安全之作爲（unsafe acts）

● 飛機水平尾翼除冰靴之更換作業原本安排在第 3 班，但第 2 班的檢查員卻主動幫忙進行更換作業。

● 第 2 班機械員拆除右側除冰靴底部的螺絲時，檢察員同時進行左右兩側除冰靴頂部螺絲的拆除。

■ 甚麼是過失醞釀狀況（error producing condition）

● 飛機因故被移出棚廠外置放。

● 第 3 班機械員在工廠內進行右側除冰靴的製作。

● 左側頂部除冰靴被拆除的螺絲未裝回。

● 該項工作未被設計爲必須檢查項目（RII）。

■ 爲什麼有防禦機制卻無效

- 機械員及檢查員，未能確實遵守飛機水平尾翼除冰靴安裝之正確品保程序。
- 公司之管理，未能確實遵守，核准之維修程序。
- 美國聯邦民航主管官署未能發現及確認所轄未遵照核准程序施工。

■ 錯誤鍊之形成如下：（詳圖 3-43）

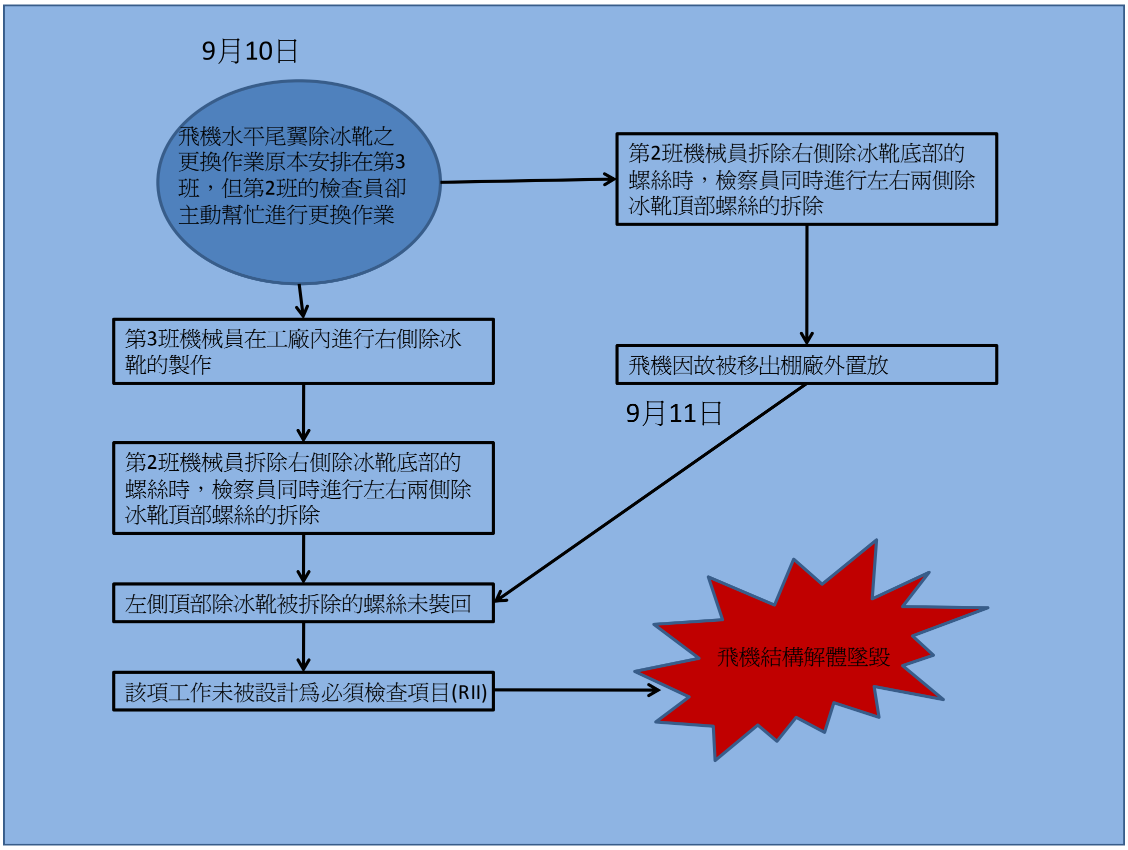


圖 3-43 錯誤鍊之形成

➢ 建立一人因訓練之計畫

■ 受訓對象

- 維修人員（Maintenance）
- 飛行組員（Crew Members）
- 飛航管制員（Air Traffic Controllers）

- 督導員（Supervisors）
- 職員（Staff）

■ 訓練課程

- 確定需求（Determine Needs）
  - 分析需要（Need Analysis）
  - 資料蒐集（Data Collection）
    - 問卷（Questionnaire）
    - 訪談（Interviews）
    - 參與人（Participants）
    - 督導員（Supervisors）
- 確定訓練型態（Determine Type of Training）
  - 警覺（Awareness）
  - 施作與回饋（Practice and Feedback）
  - 強化（Reinforce）
  - 制度化（institutionalization）
    - 教官（Instructor）
    - 評審（Evaluator）
    - 職員（Staff）
- 設計課程（Design Course）

- 教材（Curriculum）
- 班級組成（Class make-up）
  - 類別（Type）
  - 人數（Number）
  - 不咎責（Non- attribution）
  - 不懲罰（Non- retribution）
- 焦點（Focus）
- 參數（Parameter）
- 教官或電腦教學（Instructor or Computer Based）
- 引導或演講（Facilitated or Lecture）
- 測驗（Test）

- 學員（Trainees）

訓練類別	受訓者
初始訓練（Initial Training）	所有人員（All Crewmembers）
引導員訓練（Facilitator Training）	選擇人員（Selected members）
教官/評審訓練（Instructor/Inspector Training）	教 官 / 檢 察 員（Trainer/Inspector/QA）

- 訓練週期

- 工作工廠（workshop）：1 個月/次
- 引導員訓練：4 個月/次
- 複訓：6 個月/次
- 教官訓練：10 個月/次
- 每年循環不斷

肆、建議

本維修人因課程之大部分內容皆為組員資源管理（CRM）及維修資源管理（MRM）課程之教材內容，多無新意，唯獨於訓練課程章節之外，提供不少美國聯邦民航主管官署（FAA）之訓練教材及其他網站資訊，對建立一套訓練計畫及教材內容稍有助益。

本次 SCSI 授課講師為資深飛行教官，亦有多年授課經驗，但本課程主題為維修人因，尤其探討維修作業的環境，工作性質，工人素質與工作態度，公司管理文化等，非多年實務經驗者，實難深入探討，但透過分組討論，瞭解各國維修單位之管理文化，亦可為我參考與借鏡。

課程中亦陸續告之或提供不少人因訓練教材及其他網站資訊，整理如下：

FAA （2005）, *Human Factors Policy, FAA Order 9550.8A* available at http://www.hf.faa.gov/docs/508/docs/HForder.pdf#search=%22faa%20order%209550.822

FAA （2005）, *The Operator's Manual for Human Factors in Aviation Maintenance*, Washington, DC, available at http://www.hf.faa.gov/opsmanual

FAA （1996）, *Human Factors Guide for Aviation Maintenance and Inspection*, available at http://www.hfskyway.faa.gov

FAA （2003）, *The AVR R&D Requirements Process*, available at http://www.avssharepoint.faa.gov/avs/RED/TCRG/AVS%20RD%20PROCESS/Forms/AIIItems.aspx

FAA, *Airworthiness Inspector's Handbook, FAA Order 8300.10*, available at http://fsims.faa.gov/

FAA （2005）, *Advisory Circular for Repair Station Training Program*, available at http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgDAC.nsf/0/4a8218c049fc76a186256f6d00563a0d/$FILE/AC%20145-RSTP.pdf

FAA （2006）, *HBAW 06-04, Guidance for Evaluation and Acceptance for Maintenance Human Factors Training Program*, available at https://hfskyway.faa.gov/（A（Lth2wzpEywEkAAAAMDExYTU2ZGItMGQ4YS00NjViLWFkOGEtMGE2Y2JlMzA3NTdht4RiDm1ayyGq7npl13dHGb5cu4I1））/HFTest/Bibliography%20of%20Publications%5CConference%20Materials%5C2007-Conference%20Materials%5CFSDO%20Regional%20Meeting%20-%20Wichita%20（10-30-06）.pdf

檢視維修人因課程及國際間相關法規，發現 FAA 的網站內容最爲豐富及完整，建議有相關資訊需要者，可至該網站搜尋研讀即可獲得所需資訊。

附錄

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

BRITT AIRWAYS, INC., d/b/a
CONTINENTAL EXPRESS FLIGHT 2574
IN-FLIGHT STRUCTURAL BREAKUP
EMB-120RT, N33701
EAGLE LAKE, TEXAS
SEPTEMBER **11, 1991**

1. FACTUAL INFORMATION

1.1 History of the Flight

On September 11, 1991, about 1003, Central Daylight Time (CDT), Continental Express Flight 2574, an Embraer 120, operating under Title 14 of the Code of Federal Regulations, Part 135 (14 CFR 135), experienced a structural breakup in flight and crashed in a cornfield near Eagle Lake, Texas.[1]

The flight, with call sign "Jetlink 2574," departed Laredo International Airport, Texas (LRD), about 0909, en route to Houston Intercontinental Airport (IAH). Following takeoff, the flight was assigned a cruise altitude of flight level 250 (FL250). The flightcrew was later instructed to descend to FL240.

After receiving a radar handoff, the flightcrew made initial radio contact with Houston Air Route Traffic Control Center (Houston ARTCC) radar controllers for the Eagle Lake sector at approximately 0948:43. At 0954:14, Houston ARTCC instructed the flight to "...cross five five miles southwest of Intercontinental [IAH] at and maintain niner thousand." At 0954:20, the flightcrew responded, "OK fifty-five miles southwest of Intercontinental at niner thousand, we're out of flight level two four zero...."

At 0959:51, Houston ARTCC instructed the flight, "Jetlink twenty-five seventy-four, roger, fly heading zero three zero, join the Humble two three four radial GLAND, rest of route unchanged." The flightcrew responded at

[1] Unless otherwise noted, all times listed are local, CDT, based on the 24-hour clock.

095957, "Zero three zero, join the GLAND six arrival, twenty-five seventy-four." The response was the last radio transmission from the flight.

Just prior to losing radio communications with the flight, the two Houston ARTCC controllers for the Eagle Lake Sector were relieved by another controller. During the position relief briefing, all three controllers noticed the loss of the airplane radar beacon return for Jetlink 2574. At 1004:53, the radar controller, who had assumed duty, initiated the first of four attempts to contact the flight. The flightcrew did not respond. The radar controller then advised his supervisor that radio and radar contact had been lost.

The cockpit voice recorder (CVR) revealed normal conversation during the descent from FL240. Appendix E contains the CVR transcript. Following the last radio transmission, at 0959:57, the CVR recorded the flightcrew receiving automated terminal information service (ATIS) "Golf" on radio No. 2, about 1000:03.

At 1003:07, the cockpit area microphone (CAM), as recorded on the CVR, picked up sounds of objects being upset in the cockpit. These sounds were followed immediately by one that was comparable to a human "grunt."

The remaining sounds were warnings produced by the airplane's aural warning systems, as well as mechanical sounds indicating breakup of an aircraft in flight. The sound of wind was picked up by the CAM, beginning at 1003:13. The CVR tape stopped at 1003:40, about 33 seconds after the onset of the sound of objects being upset in the cockpit. The entire CVR recording lasted for 31 minutes and 6 seconds.

Radar data and a readout of the airplane's flight data recorder (FDR) showed the airplane in descent, passing through about 11,800 feet mean sea level (msl), when a sudden pitchover occurred. The FDR data showed that there was then a sudden negative vertical acceleration of at least 3 1/2 negative g, as well as roll and yaw moments, heading changes, and sudden changes in engine parameters.[2]

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[2] 1 g equals 1 times the force of gravity. The FDR was limited in negative vertical acceleration readout to 3.375 negative g. The data reached that point on several occasions, following the initial negative acceleration. Appendix F contains relevant FDR data plots.

Prior to the pitching over of the airplane, the engines were operating normally. At the start of the sudden pitchover, FDR data revealed a sudden oscillation in propeller speed, recorded in percentage of standard revolutions per minute (rpm). Propeller rpm initially decreased from what had been a constant 85 percent for both engines. However, within 2 seconds, the rpm for both engines increased. No. 2 engine rpm decreased again, but then increased to well over 100 percent until the data ended.

All the eyewitnesses who were interviewed observed the occurrence from the ground. A total of eight witnesses reported that they saw the airplane for at least part of the time after they realized it was in distress, until impact.

The following describes various eyewitness observations of the airplane:

- flying normally
- wings level, slightly nose down3
- suddenly consumed by fireball
- wingtips and part of tail protruding from fireball
- a bright flash
- orange or red-orange flames at time of flash or immediately thereafter
- sputtering engines, followed by three pops
- a revving sound
- a flat spin to the left until impact
- left wing dangling from blown out area
- right wing missing

[3] Manufacturer-provided data indicate that a negative 10-degree pitch angle (before the sudden attitude and other changes) is normal and could be expected for the conditions of the accident flight.

- flying parts during downward spiral

After impact, the airplane was upright, in a wings-level attitude, partially imbedded in the ground and burning.

Local fire and rescue personnel responded to the crash and extinguished the fire. All persons aboard the airplane were fatally injured, and the bodies of two of the occupants were lying outside of the airplane. Both pilots were still strapped in their seats.

The accident occurred in visual meteorological conditions (VMC), **in** daylight. The main **wreckage,** including the cockpit and cabin, came to rest at 29° 30' 98" north latitude and 96° 23' 21" west longitude.

1.2 Injuries to Persons

	Flightcrew	Cabincrew	Passengers	Other	Total
Fatal	2	1	11	0	14
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	4	0	-Q	--	0
Total	2	1	11	0	14

1.3 Damage to Aircraft

The airplane was destroyed in the crash and fire. The airplane was valued at around $7.75 million.

1.4 Other Damage

There was no claim for damage to the harvested cornfield and pasture land into which the main wreckage and other portions of the airplane fell.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 29, was born on April 20, 1962. He was hired by Continental Express Airlines on October 10, 1987. He held airline transport pilot certificate No. 565336474, with ratings for the EMB-120 and Airplane Multiengine Land. His most recent Federal Aviation Administration (FAA) first-class medical certificate was issued on July 18, 1991, with the limitation: "Holder shall wear correcting lenses while exercising the privileges of his airman certificate." Company records indicate that at the time of the accident the captain had accumulated approximately 4,243 total flying hours, of which 2,468 were in the EMB-120.

The captain received his initial ground school and proficiency check in the EMB-120 as a first officer, completing the training on October 29, 1988. He completed upgrade ground school training on September 21, 1989, and received a type rating in the EMB-120 on September 29, 1989. He completed his initial operating experience and received a line check on October 2, 1989. His last proficiency check was on March 9, 1991. His last recurrent training was completed on May 29, 1991, and his last line check was accomplished on August 8, 1991.

1.5.2 The First Officer

The first officer, age 43, was born on November 9, 1947. He was hired by Continental Express Airlines on March 12, 1990. He held airline transport pilot certificate No. 1963386, with ratings for the EMB-120 and Airplane Multiengine Land. His most recent FAA first-class medical certificate was issued on August 30, 1991, with no limitations. Company records indicate that, at the time of the accident, the first officer had accumulated approximately 11,543 total flying hours, of which 10,300 were obtained prior to his employment with Continental Express. He had a total of 1,066 hours in the EMB-120.

The first officer completed initial ground school in the EMB-120 on March 30, 1990. He completed flight training on April 19, 1990. His initial operating experience and line check were completed on April 24, 1990. He was subsequently upgraded to captain on the EMB-120, completing that training and initial operating experience on May 14, 1990. Although he no longer held a regular captains bid number, the airline allowed the first officer to retain his currency as a captain. He received proficiency checks on October 29, 1990, and April **11, 1991.**

1.5.3 Management and Maintenance Personnel

The president, age 51, was hired in July 1990, as President of the Commuter Division of Continental Airlines, Inc. Continental Express is a wholly owned subsidiary of Continental Airlines. He had worked previously for Eastern Airlines (owned by the same parent company as Continental and Continental Express), from January 1987 to July 1990, in several successive positions: Staff Vice President and Counsel for Regulatory Compliance; Vice President for Base Maintenance; Special Assignment; and Vice President for Administration. Prior to his employment with Eastern Airlines, he had worked for New York Air (1980-1986) and had served as its Vice President for Operations. He holds a commercial pilot certificate with ratings and limitations of airplane single engine land with instrument privileges. He also holds a private pilot certificate with ratings and limitations of airplane multiengine land.

The Senior Director of Maintenance and Engineering, age 48, was hired in August 1990. He had worked previously for Eastern Airlines, from September 1989 to August 1990, as Manager of Special Projects. From June 1987 to June 1989, he worked for Aloha Airlines, first as Director of Quality Control and then as Director of Maintenance. His Airframe and Powerplant License was issued on April 10, 1968.

The Senior Director of Quality Assurance and Control, age 46, was hired in February 199 1. He had worked for Eastern Airlines from 1969 to 1991 and had served as Manager of Aircraft Inspection. His Airframe and Powerplant certificate was issued on June 26, 1979.

The second shift supervisor, age 28, who was in charge of N33701, was hired by Continental Express on April 9, 1988, as a mechanic. He was promoted to shift supervisor on January 19, 1990. His previous employment included service with the U. S. Army from 1982 to 1985. His Airframe and Powerplant certificate, number 383749034, was issued on December **19, 1987.**

The second shift inspector, age 25, who removed the attaching screws from the tops of the left and right horizontal stabilizer leading edge assemblies, was hired on July 11, 1989, as a mechanic. He was promoted to inspector on October 24, 1990. His previous employment included service as an aircraft electrician in the U. S. Navy. His Airframe and Powerplant certificate, number 456456725, was issued on February **5, 1989.** The inspector had received company discipline on two occasions that related to inspections. In August 1991, he received a warning for having "missed a crack...in inspection of engine exhaust stack." He received a second warning that month because he "did not finish all paperwork **required...missed** 15 task cards on the accountability sheet."

The company had a written policy for disciplinary action that included the following forms of progressive discipline: verbal counseling or reprimand; formal counseling and written warning; probation; suspension; dismissals; and immediate dismissal without notice. According to the written policy, "there is no precise formula for applying discipline" so no specific action would be taken after a specific number of warnings.

The second shift mechanic, age 43, was hired on July 2, 1990, as a mechanic. His previous employment included work as an aircraft mechanic with Continental Air Micronesia **(1989-1990),** and flight line mechanic and inspection dock chief with the U. S. Air Force (1986-1989). He holds Airframe and Powerplant certificate number 45 1760789 issued on March **7, 1990.**

The second shift supervisor, age 29, (who was not responsible for **N33701),** was hired on October 25, 1987, as a mechanic. He was promoted to inspector in 1989 and to shift supervisor on January 19, 1990. He was previously employed as an airplane mechanic for two fixed-based operators (1987) while he completed school. His Airframe and Powerplant certificate, number 451396613, was issued on January **26, 1988.**

The third shift supervisor, age 26, was hired by Britt Airways, Inc., (later merged into Continental Express), on June 8, 1987, as a mechanic at the air carrier's Cleveland base. He was promoted to an inspector on November 27, 1989, transferred to the Houston base as a mechanic on March 16, 1990, and was promoted to shift supervisor on August 17, 1990. His previous employment included work as a helicopter mechanic and crew chief in the U. S. Army **(1984-86),** and as a jet engine mechanic in the U. S. Air Force Reserves (1986-87). His Airframe and Powerplant certificate, number 312767386, was issued on June **16, 1989.**

The third shift inspector, age 36, was hired by Britt Airways, Inc., (later merged into Continental Express), as a maintenance helper at the Bloomington, Indiana, base on September 1, 1982. He was promoted to aircraft mechanic in 1986. In 1989, he spent 9 months at the Houston base where he was promoted to inspector. He returned to the Houston base as an inspector on May 1, 1991. His Airframe and Powerplant certificate, number 347508432, was issued on April26, 1986.

The hangar workers, consisting of mechanics, inspectors, and supervisors, who were directly involved in work on the tail structure of the airplane, represented about 23 percent of the second shift workers and 21 percent of the third shift workers employed by Continental Express at the time of the accident. Together, they represented about 15 percent of the entire hangar workforce from all shifts.

1.6 Aircraft Information

1.6.1 The Airplane

The airplane, U.S. registration N33701, was an Embraer EMB-120, manufactured in Brazil. The serial number was 120-L77. Continental Express Airlines acquired the airplane on April 15, 1988. Records showed that the airplane had accumulated 7,229.8 hours and 10,009 cycles as of September 10, 1991. The airplane was configured with 10 rows of double passenger seats on the right side of the cabin and 10 rows of single passenger seats on the left side of the cabin.

The gross takeoff weight for the airplane, upon departure from LRD on the accident flight, was calculated by the flightcrew as 22,272 pounds, including 1,815 pounds for passengers, 259 pounds for cargo, and 3,100 pounds for takeoff fuel. The calculated weight for the takeoff from LRD was 3,081 pounds below the maximum allowable takeoff weight of 25,353 pounds.

The airline's EMB-120 Aircraft Operations Manual stated, "The balance of the aircraft is controlled by the load in the aft cargo hold. To keep aircraft CG [center of gravity] within allowable limits, there are minimum and maximum loads for the aft cargo hold which vary as the passenger load varies."

A table provided in the airline's Alert Bulletin 91-17, dated September 3, 1991, established a minimum weight of 78 pounds and a maximum weight of 794 pounds for a passenger load of 11 persons. The documented load of 259 pounds in the aft cargo hold was within CG limits.

1.6.2 Maintenance Information

The procedures for maintaining the airplane were contained in the airline's General Maintenance Manual (GMM), which was approved by the FAA (See section 1.17.2). A review of the maintenance records for N33701 was conducted, and personnel responsible for the maintenance and inspection of N33701 the night before the accident were interviewed (See section 1.17.1).

1.7 Meteorological Information

There were no significant meteorological information (SIGMET) advisories or center weather advisories **(CWAs)** in effect for the area before or after the time of the accident.

The weather conditions reported by the National Weather Service for Palacios, Texas, which was the nearest reporting station to the accident site, were:

> 0950 (about 15 minutes prior to the accident):
>
> Estimated ceiling 3,000 feet broken, 10,000 feet broken, 25,000 feet overcast, visibility 6 miles, haze, temperature 83 degrees, **dewpoint** 74, wind 070 degrees at 7 knots, altimeter 30.08.
>
> At 1050, about 45 minutes after the accident, the reported weather at Palacios, Texas, was:
>
> Estimated ceiling 3,000 feet broken, 10,000 feet broken, 25,000 feet broken, visibility 7 miles, haze, temperature 86 degrees, **dewpoint** 74, wind 070 degrees at 7 knots, altimeter 30.03.

1.8 Aids to Navigation

At 095951, Houston ARTCC directed the airplane to "**...fly** heading zero three zero, join the Humble two three four radial GLAND, rest of route unchanged." This radio transmission was the last one that the flight acknowledged.

At the time of the accident, the airplane was in a descent under positive radar control by Houston ARTCC, Eagle Lake Sector, and had been instructed to intercept the radial. There were no difficulties regarding aids to navigation or air traffic control (ATC) reported in this accident.

1.9 Communications

Houston ARTCC's communications with the flight took place for approximately 11 minutes, beginning at 0948:43, when the flight reported in, "Houston Center Jetlink twenty-five seventy-four flight level two four zero." The last transmission from the flight occurred at 0959:57, with Jetlink 2754 acknowledging Houston ARTCC's instructions to "...join the GLAND six arrival...." (See appendix E).

Neither the CVR nor ATC tapes indicate any communication difficulties between the crewmembers nor between the flight and air traffic controllers until after communications in the airplane and from the airplane were lost. From the beginning of the CVR recording, at 0933:36, until the sound of objects moving in the cockpit, at 1003:07, there is no difficulty indicated in any of the communications or background sounds. The first officer, however, remarked at 0936:29, "Do you smell something like paint thinner?" and the captain replied, "A little bit, yeah."

The first indication that there might have been some difficulty was the lack of response to three calls from the Houston ARTCC Eagle Lake Sector controller to "Jetlink twenty-five seventy-four, say altitude," at 1004:53, 1005:12, and 1005:32. All three controllers for the Eagle Lake Sector (two outgoing and one incoming) noted about the time of the change to the relief controller that the radar return for Jetlink 2574 had disappeared from the screen.

1.10 Aerodrome Information

The flight was inbound to IAH. The airport elevation is 98 feet msl. The airport is operated continuously. There are four primary nonintersecting runways, the longest of which, 14L/32R, is 12,000 feet long by 150 feet wide.

There were no difficulties reported regarding any aerodrome in this accident.

1.11 Flight Recorders

The CVR and FDR were recovered from their installed positions in the aft portion of the airframe. There was minor damage to the recorder cases from impact forces. The recorders showed no evidence of having been subjected to fire. The CVR recording was clear and showed no evidence of loss in quality as a result of crash damage. The FDR recording was also of good quality.

1.12 Wreckage and Impact Information

Separated parts of the airplane, including all eight propeller blades, were within about a 1.5 nautical mile radius of the main wreckage.

The horizontal stabilizer, or top of the T-type tail, had separated from the airplane before impact and was lying about 650 feet west-southwest of the main wreckage. Some of the structure and skin from approximately the upper third of the vertical stabilizer were still attached to the horizontal stabilizer. The lower two thirds of the vertical stabilizer remained attached to the tail cone in the main wreckage. The leading edge/deice boot assembly for the left side was missing from the horizontal stabilizer. The left side leading edge/deice boot was later found by investigators in a small corral about 3/4 mile west of the main impact site.

The left engine and propeller assembly, minus the four propeller blades, was lying approximately 370 feet south-southeast of the main wreckage. The left wing was in the wreckage, still attached to the fuselage by the lower attachment points, but it was folded under the fuselage and the inboard portion of the right wing. The right wing was in its proper position, still attached to the main fuselage. Part of the right wing tip was found about 1/5 mile west of the main impact site. The right engine remained attached to the right wing, and the four propeller blades were separated from the propeller hub assembly.

Both engines and propeller systems, including the eight separated propeller blades, were sent to the facilities of the engine manufacturer for disassembly and inspection, under the supervision of the Safety Board. The disassembly and inspection determined that the right engine had over-sped and overtorqued before impact. The left engine had no evidence of over-speed or overtorque. The eight propeller blades that had separated from their attaching points to the hubs, and the hub side attaching points, were fractured. There was no evidence of a defect or anomaly in either engine or propeller assembly prior to the unusual attitudes and in-flight breakup of the airplane. The damage to the engines and propellers was compatible with the results of extreme changes in airplane attitudes, and, in the case of the left engine, separation from the airplane before ground impact.

The Colorado River, flowing approximately north to south, ran about 1.2 miles west of the main crash site. An agricultural pilot, who flew over the crash site shortly after impact, reported seeing a piece of airplane wreckage floating down the river. However, investigators did not find any wreckage in the river.

During the Safety Board's examination of the wreckage, none of the 47 screws that would have attached the upper surface of the leading edge assembly for the left side of the horizontal stabilizer was found. There was no evidence of distress in the upper attachment holes for the left side leading edge assembly or indication that the attaching screws were installed when the left side leading edge assembly separated from the horizontal stabilizer. In addition, a "lip" was formed on the forwardmost frame on the left lower side of the horizontal stabilizer spar cap. That frame (spar cap), with receptor holes for the lower attaching screws, was the area into which the screws mounted the underside of the left side leading edge assembly to the stabilizer. This lower frame area showed signs of distress. Figures la through 1d show the condition of the left horizontal stabilizer leading edge.

The lower attachment screws remained installed, but the leading edge assembly had separated from the stabilizer, with the exception of a small portion of composite structure remaining below the two farthest inboard screw heads. The spar cap on the lower left side of the horizontal stabilizer showed evidence of being pulled down so that it would project into the wind stream along with the leading edge. This pulling damage is consistent with the left side leading edge assembly having been ripped down and away from the lower attaching screws as it separated from the horizontal stabilizer. This evidence was consistent with screws missing on the top side of the left leading edge assembly, and the lower attaching screws holding fast, pulling down the frame (spar cap) on the lower side of the stabilizer, and thereby forming the lip.

The main portion of the airplane came to rest upright and partially imbedded in the cornfield on a heading of about 360 degrees. There was no indication that the main wreckage moved after initial ground impact.

The crash site was approximately 3 miles south-southwest of the town of Eagle Lake, Texas, and 60 nautical miles west-southwest of **IAH.**

Figure 1 a.--View of horizontal stabilizer from underside.

Figure lb.--Leading edge assembly and outboard portion of left side of horizontal stabilizer.

Figure lc.--Front frame of left side of horizontal stabilizer
with lower screw attaching area angled downward.

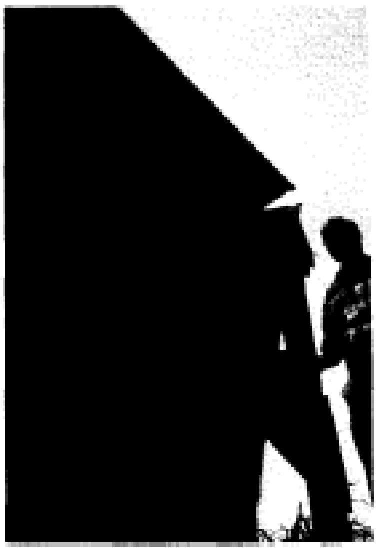

Figure ld.--View of interior leading edge assembly for left side
of horizontal stabilizer.
Note that upper screw attachment holes (lower) show no signs of distress.

The nose section and the bottom surface of the forward section of the fuselage were crushed. The extreme aft section of the fuselage, including the still attached upper 2/3 of the vertical stabilizer, had compression impact damage.

The fuselage cargo door that was found 18 feet from the main wreckage had deep grooves and scratches in the outer skin. Instantaneous overloading was apparent on the bayonet fittings and roller attachments at the forward and aft cargo door frames. The lower half of the cabin boarding door remained attached to the fuselage; and the door operating handle was in the stowed position. The main landing gears and the nose gear were in their stowed positions. The nose landing gear was displaced upward by impact forces.

1.13 Medical and Pathological Information

1.13.1 Flightcrew and Passengers

Autopsies performed on the 3 crewmembers and 11 passengers by the Harris County Coroner's Office, Texas, determined that all occupants sustained fatal traumatic injuries consistent with sudden impact. Two occupants were ejected from the aircraft at impact. Most persons who were found inside the airplane were subjected to the postimpact fire. No evidence of preimpact fire injuries or smoke inhalation by occupants was found.

Toxicological analyses were completed on specimens of the captain's blood and urine and on other tissues of the first officer and flight attendant because samples of their blood and urine were not available. The captain's test results were negative for carbon monoxide, hydrogen cyanide, alcohol, and other licit and illicit drugs. Test results of the first officer and flight attendant were negative for licit and illicit drugs except alcohol. A liver sample from the first officer tested positive for alcohol at a level of .06 percent, and a bile sample from the flight attendant tested positive for alcohol at a level of .07 percent. Evidence of heat coagulation was noted in all tissue samples of the first officer and flight attendant that were examined. Heat exposure can accelerate putrefaction and post-mortem production of alcohol. A second testing of samples by another laboratory found higher levels of alcohol, but the laboratory director noted that putrefaction of the samples had occurred prior to their arrival at the laboratory.

1.13.2 Maintenance Personnel

During the on-site portion of the investigation, a request was made by the Safety Board for urine and blood samples from the 12 persons who had been involved in the maintenance of the airplane on the evening and midnight shifts on September 10 and 11, 1991. They included two mechanics, two supervisors, and an inspector from the second or evening shift; and four mechanics, two supervisors and one inspector from the third or night shift.

Blood and urine samples were obtained by the airline's office of Human Resources and Drug Abatement. The samples were obtained for 11 of the individuals during the night work period of September 14 through 15, and from the remaining person the following morning, September 15, 1991. The samples were provided to the Safety Board and were tested. All test results were negative for alcohol and drugs of abuse.

1.13.3 Air Traffic Control Personnel

About 1300, September 11, 1991, 2 hours after the accident, the Safety Board asked the FAA for urine and blood samples from the air traffic controllers at the Houston ARTCC. Samples were voluntarily provided by the two controllers who last spoke to the flightcrew. Also, samples were provided by the controllers' two supervisors. The samples were submitted and retained under Safety Board authority.

Because there was no evidence of air traffic controller involvement in the accident, the samples obtained from the two controllers and their supervisors were not analyzed. The samples were subsequently returned to these individuals.

1.14 Fire

There was a fire in flight, as well as after ground impact. This was confirmed by eyewitnesses and wreckage examination.

The horizontal stabilizer and about 1/3 of the upper vertical stabilizer had separated from the airplane before ground impact. The horizontal stabilizer, with about 3 feet of the uppermost vertical stabilizer still attached, contained some light soot deposits. A broken edge of composite material that spanned the upper surface of the horizontal stabilizer, along the center line of the horizontal stabilizer, showed a small burned area. Although there were bits of molten aluminum splattered on the lower two thirds of the vertical stabilizer, there was no evidence of molten aluminum splatters on the upper portion of the vertical stabilizer or the horizontal stabilizer.

The lower two thirds of the vertical stabilizer that remained attached to the fuselage was found in place in the main wreckage. Bits of molten aluminum were found splattered on the left surface of this lower portion of the vertical stabilizer.

Approximately the lower half of the primary and secondary rudder control surfaces that remained attached to the lower portion of the vertical stabilizer showed heat damage, including molten aluminum splatters. The upper half of the rudder control surfaces, which was found as a unit in a field approximately 4/10 mile west of the main wreckage, showed no evidence of smoke deposits or fire damage. The upper and lower sections of the rudder control surfaces were placed together, and a clear demarcation line was seen where the rudder surfaces had broken.

1.15 Survival Aspects

The accident was not survivable.

The police chief learned about the accident about 1010, and the first of two 350 gallon, four-wheel drive mini-pumper fire trucks arrived at the accident site around 1020. The fire was nearly extinguished when the first truck arrived, and limited effort was required to extinguish the remaining flames. In total, about 12 volunteer firemen and 6 ambulances responded to the crash.

1.16 Tests and Research

1.16.1 Airplane Performance

The airplane was flying to the northeast on a 44-degree heading at the time radar contact was lost at 1003:06 CDT. Figure 2 shows the radar-derived ground track of flight 2574, selected sounds from the CVR, and the wreckage distribution.

Figure 3 provides a closeup view of part of the ground track and wreckage distribution. The piece of airplane structure farthest from the main wreckage was the left side leading edge (LE) of the horizontal stabilizer. The LE

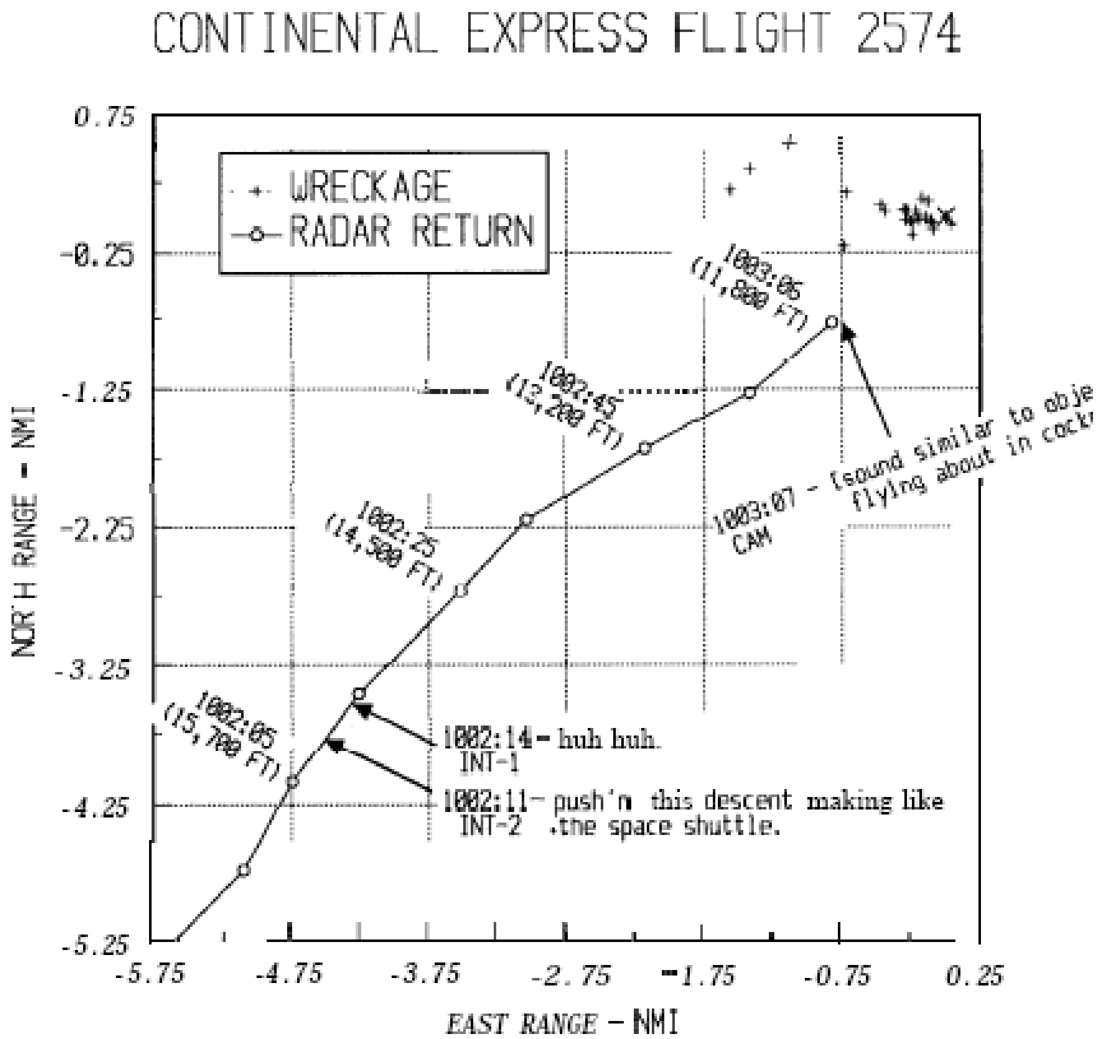

Figure 2.--Radar-derived ground track, CVR sounds, and wreckage distribution.

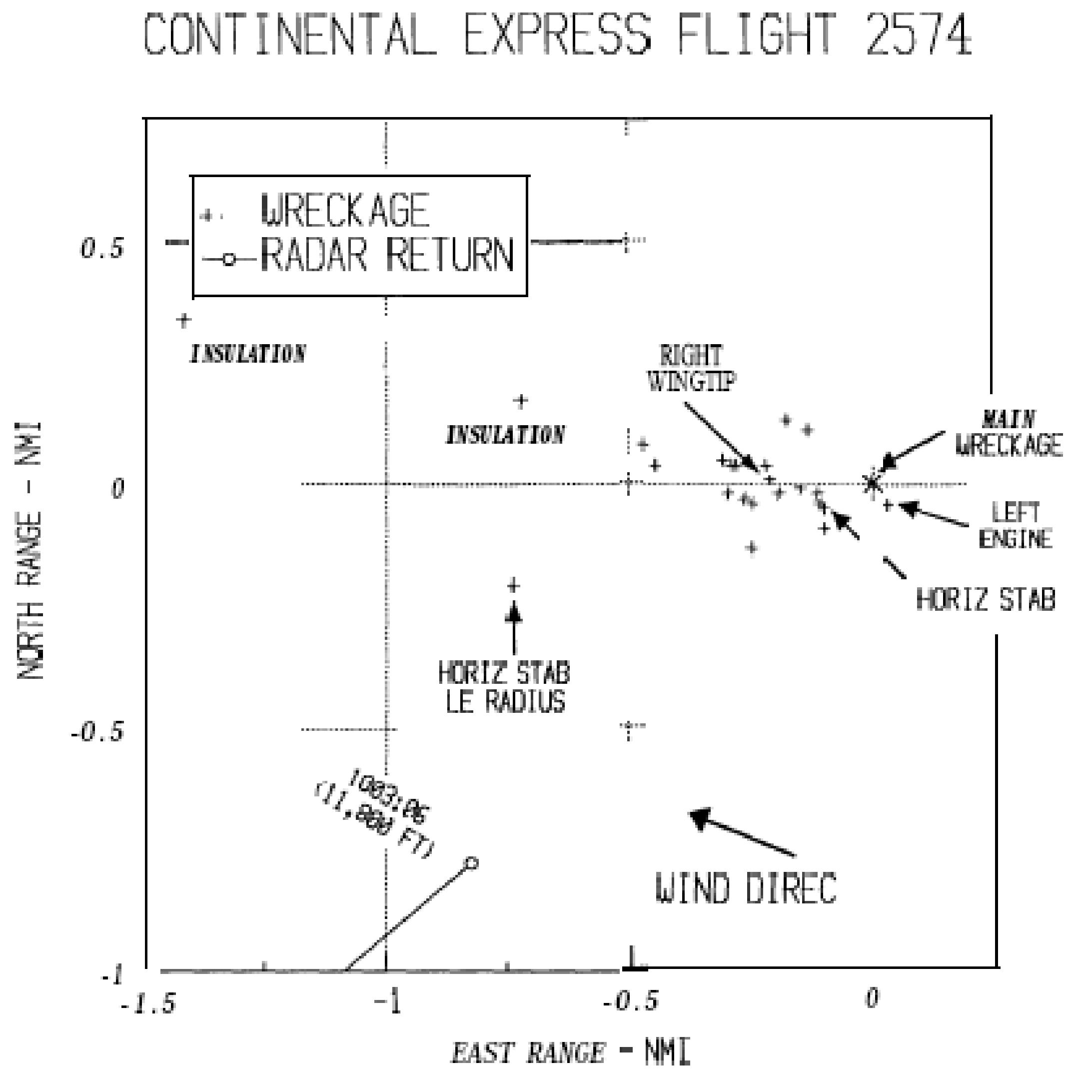

Figure 3.--Closeup view of part of ground track and wreckage distribution.

was the first piece of structure along the flight's northeasterly ground track, preceding the next piece by roughly 1/2 of a nautical mile.

Figure 4 shows the radar-derived descent profile. The last radar contact occurred as flight 2574 was descending through 11,800 feet. The radar-derived rate of descent during the final minute was approximately 4,000 feet-per-minute, which is consistent with FDR data from the airplane.

The Safety Board used FDR data, CVR data, and engineering calculations from Embraer to study the motion and breakup of the airplane during the accident sequence. The flight dynamics of the accident were simulated by Embraer at the request of the Safety Board. Flight parameters at the time of the in-flight upset, including airspeed, altitude, acceleration, and airplane attitude, were examined. The leading edge separation from the left horizontal stabilizer was examined, as was the separation of the entire horizontal stabilizer from the airframe. The known flight characteristics of the airplane, before the sudden in-flight changes, were used to examine the events during the accident sequence.

The FDR data show that the airplane was descending through 11,500 feet (pressure altitude) at 260 knots indicated airspeed (KIAS) when it abruptly pitched down and entered a steep dive. The airplane was 12 knots below the upper limit (272 KIAS) of the EMB-120 airspeed envelope when the upset occurred. The FDR data showed that a negative load factor of at least -3.375 g was reached about 1 second after the upset, with a corresponding decrease in airplane pitch attitude. The peak negative acceleration is unknown because the FDR's recording limit of -3.375 g was reached. The normal acceleration then fluctuated between about -0.6 and -2.4 g until the lower recording limit was reached again, 6 1/2 seconds after the upset began. At that point, the data show the airplane descending through 9,500 feet at 280 KIAS.

During the first 6 1/2 seconds after the upset began, the data showed a roll of 10 to 15 degrees right wing down and a nose-left heading move from 52 to 33 degrees. During the same period, the lateral acceleration was as much as 1/2 g.

After the 6 1/2 second period, the airplane abruptly rolled to the right more than 160 degrees in 1 second. During that 1 second, the airplane pitch attitude reached the minimum recorded value of -86 degrees, and then it began increasing. Normal acceleration went from about -0.5 to +2 g. Lateral acceleration went from about -.05 g to the recorded positive limit of +1 g, stayed at that limit for

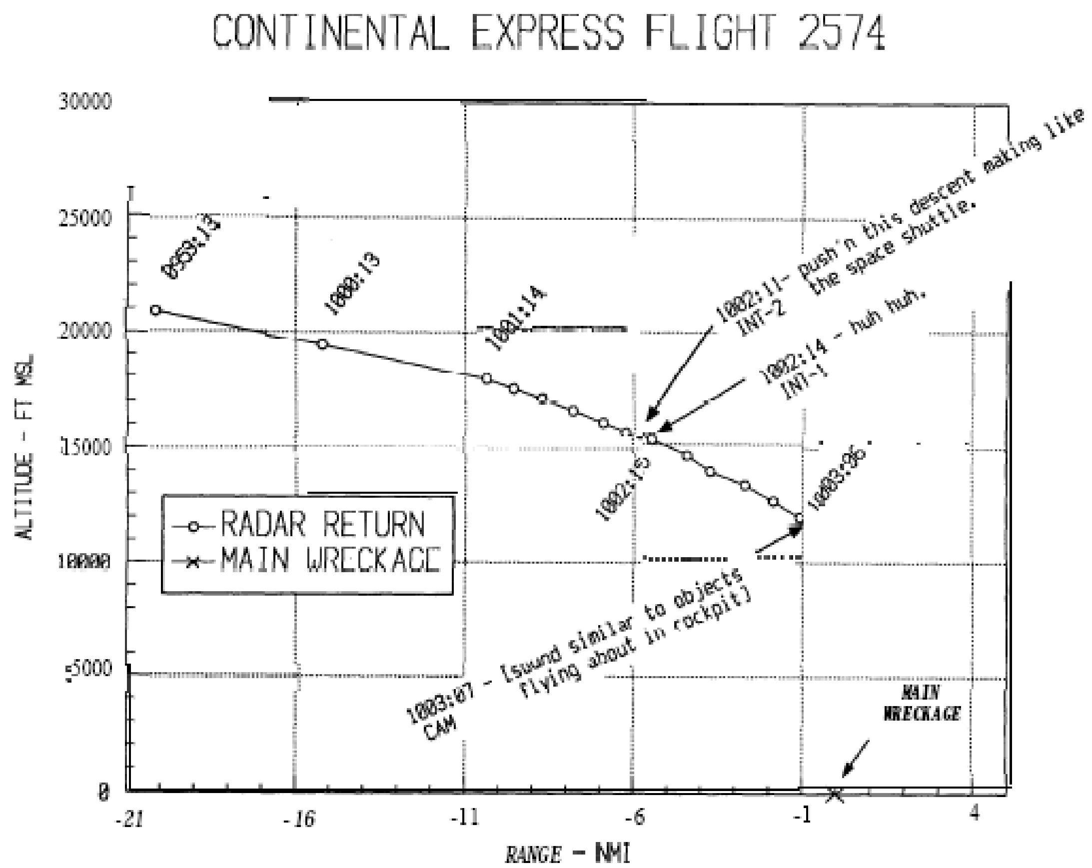

Figure 4.--Radar-derived descent profile.

several seconds, and then went to the negative limit of -1 g before the FDR ceased operation.

According to Embraer EMB- 120 engineering data, the horizontal stabilizer angle of attack in steady-state flight at 260 KIAS is -2 degrees. An aerodynamic stall (loss) of the left side horizontal stabilizer reduces the downward lift vector (downforce) at the tail (which is needed to maintain steady flight), and a large nose-down pitching moment is produced that leads to a negative wing stall. Calculations show that the wing stall occurs within 1 1/2 seconds of the tail stall, with a peak negative acceleration of about -5 g.

Two dynamic flight simulations were conducted in an attempt to determine whether the data obtained from the FDR would match the circumstances of a sudden loss of the left stabilizer leading edge or a sudden loss of the entire horizontal stabilizer. The results of the two simulations are shown in Appendix H. Because of limitations in available FDR data and the highly dynamic motion, the flight dynamic predictions could only examine the first 1 1/2 seconds of the flight after the upset.

Neither simulation could precisely duplicate the performance of the accident airplane as recorded by the FDR. The first simulation (that assumed a sudden loss of the left horizontal stabilizer leading edge) showed a less severe pitch down and negative load factor, while the second simulation (that assumed loss of the entire horizontal stabilizer) was more severe than the FDR data recorded for the accident flight. The first simulation incorporated a loss of downforce and increase in drag that are estimated and consistent with standard aerodynamic practices. Because lift from the horizontal stabilizer was directed downward, a transient rise in normal acceleration occurred after the leading edge detached and the downward lift was lost. In the first simulation, this "g" increase was equivalent to 1/2 of the downforce produced by the horizontal stabilizer. A transient rise in acceleration also exists in FDR data. However, lift and drag forces would change significantly during the dynamic motion of the airplane and would be virtually impossible to duplicate exactly in an engineering simulator.

Calculations made by Embraer of the lift required from the horizontal stabilizer during both postmaintenance flights show that the peak stabilizer downforce occurred at the time of upset on the accident flight. The maximum downforce produced by the horizontal stabilizer during the previous flight was at least 30 percent lower than that achieved just prior to the accident.

Embraer was asked to provide the Safety Board with a structural analysis report to evaluate the effects of airloads on the airplane structure after separation of the left horizontal stabilizer leading edge, The calculations showed that the predicted airloads on the horizontal stabilizer and vertical stabilizer structure for a loss of the leading edge did not exceed the maximum allowable load for the vertical and horizontal stabilizers.

The airspeed experienced at the time of the in-flight breakup, 260 KIAS, while below the manufacturer's maximum allowable airspeed of 272 KIAS, was the highest airspeed experienced on either flight following the maintenance. The highest airspeed recorded on the FDR on the first flight of the day, from IAH to LRD, was 216 KIAS.

1.17 Additional Information

1.17.1 Maintenance Records Review--General

The Safety Board examined in detail the recent maintenance history of N33701 related to the work conducted on the horizontal stabilizer. This effort involved a review of paperwork and procedures and extensive interviews of maintenance personnel associated with the work on the airplane the night before the accident. Additionally, the past full year of records were examined for items related to airworthiness directive (AD) actions and actions related to engine/propeller and flight control discrepancies. Further, the Safety Board reviewed Continental Express' FAA-approved General Maintenance Manual (GMM) and its required inspection item (RII) program.

No discrepancies were noted with AD compliance. Certain discrepancies were noted with respect 'to actions taken during a past replacement (April 24, 1991) of the right elevator on N33701, and as the result of an overtorque on the No. 1 engine (September 24, 1990). See sections 1.17.5 and 1.17.6 for additional details.

1.17.2 General Maintenance Manual (GMM)

The Continental Express GMM had FAA-approved procedures. GMM 1, Section 1, Paragraphs 1-6, states that "personnel performing maintenance will follow and be familiar with the instructions as outlined herein....Instructions and information, contained herein, bring Continental Express into compliance with the appropriate Federal Aviation Regulations. For this reason, it is essential that the contents be followed."

GMM 1, Section 3, Paragraph 10, specifies that it is imperative for maintenance/inspection forms to be completed to ensure that no work item is overlooked. Such work includes the completion of maintenance/inspection shift turnover forms, so that oncoming supervisory personnel can be made aware of complete/incomplete work, and the documentation of incomplete work that the mechanic can note on the reverse side of the M-602 work cards. GMM 1, Section 5, Paragraph 7, specifically addresses several methods to ensure proper turnover during shift changes. These methods include briefings by mechanics to supervisors and briefings by outgoing supervisors to incoming supervisors.

The GMM contained provisions for a lead mechanic position in the organizational structure of the maintenance department. That position was not filled at the IAH maintenance base. According to the FAA maintenance inspector responsible for oversight of the Continental Express maintenance facilities, the lead mechanic position was identified in the organizational structure of one of the merger airlines. That position did not exist at the other merger airline. Instead, the supervisor was assigned to perform the functions assigned to the lead mechanic. Therefore, the lead mechanic position did not exist at the IAH maintenance base and, according to the FAA inspector, would not be considered a deviation from or violation of the provisions of the GMM for the Houston base.

1.17.3 Horizontal Stabilizer Maintenance

The review of the maintenance records for N33701 revealed that on August 26, 1991, during the airline's fleet-wide campaign to examine aircraft deice boots for winter operation, a quality control inspector had noted both leading edge deice boots as "watch list" items on M-602 work cards because of "dry rotted pin holes entire length" [of the boots]. On September 10, 1991, the night before the accident, Continental Express' Maintenance Control office scheduled both horizontal stabilizer leading edge deice boots on N33701 for replacement.

A series of interviews was conducted from September 13 through 16, 1991, and from October 22 through 24, 199 1, with airline maintenance personnel, inspectors, and supervisors who were working the night before the accident. These personnel worked on the airplane on the second or "evening" shift and third or "midnight" shift. During the first series of interviews, seven mechanics, four maintenance supervisors, and three quality control inspectors were interviewed.

During the second series, one mechanic, one inspector, and two supervisors were reinterviewed; and two senior directors and two FAA principal maintenance inspectors were interviewed for the first time.

The interviews revealed that the night before the accident, the airplane was pulled into the Continental Express hangar at IAH during the second shift at about 2130 hours for scheduled maintenance. The scheduled maintenance included the removal and replacement of both the left and right horizontal stabilizer deice boots.

A change of either the left or right deice boot required that the leading edge/deice boot assembly for that side of the horizontal stabilizer be removed from the stabilizer. Normally, while still attached to the stabilizer, the old deice boot would be stripped from the composite structure of the leading edge, the deice fluid lines would be disconnected, and the leading edge would be removed and a new deice boot bonded on. Then, the leading edge/deice boot assembly would be reinstalled on the horizontal stabilizer by means of approximately 47 attaching screws for each of the top and bottom sides of the assembly.

Two second shift mechanics, with the assistance of an inspector, gained access to the T-tail, which was about 20 feet above the ground, by means of a hydraulic lift work platform. The work was assigned by the second shift supervisor who took charge of N33701. The two mechanics removed most of the screws on the bottom side of the right leading edge and partially removed the deice boot bonded to the front of the right side leading edge.

The inspector who had climbed on top of the T-tail had removed the attaching screws on the top of the right side leading edge and then walked across the T-tail and removed the attaching screws from the top of the left side leading edge. The bottom screws that continued holding the horizontal stabilizer leading edge assembly in place were not removed. The top sets of attaching screws for both the left and right horizontal stabilizer leading edge assemblies were not visible from the ground.

The right leading edge assembly was removed from the horizontal stabilizer following a shift change by third shift mechanics. A new deice boot was bonded to the front of the leading edge at a work bench inside the hangar. During the third shift, the accident airplane was pushed out of the hanger to make room for work on another airplane. There was no direct light placed on the airplane as it sat outside the hangar. Work on the horizontal stabilizer was resumed outside. The third shift mechanics reinstalled the right side leading edge assembly. They used new and used screws to attach the top and bottom of the assembly to the right horizontal stabilizer.

The second shift work on N33701 was indicated on the second shift inspector's written turnover sheet; however, the incoming third shift inspector reviewed the sheet before the entry was made. The third shift maintenance supervisor and mechanics were not verbally informed of the removal of the upper **screws** on the left side leading edge. The M-602 work cards had originally been assigned to the third shift for completion, but the second shift supervisor, who was assigned to N33701, elected to start work on the deice boots to assist the third shift with the workload. In addition, he did not issue the M-602 work cards to the second **shift** mechanics because they were in a package assigned to the third shift. As a result, no entries were made on the reverse sides of the M-602 work cards that would have informed the third shift supervisor and third shift mechanics that work had been started by the second shift on both the left and right horizontal stabilizer deice boots.

A third shift inspector later reported that he had gained access to the top of the horizontal stabilizer to assist with the installation and inspection of the deice lines on the right side of the horizontal stabilizer. He stated that he was not aware of the removal of the screws from the top of the left leading edge assembly of the horizontal stabilizer. In the dark outside the hangar, he did not see that the screws were missing from the top of the left side leading edge assembly for the horizontal stabilizer.

Based on information gathered from interviews and statements, the following significant maintenance events took place the night before the accident:

2000: The second shift supervisor, who was in charge of a **"C"** check on another airplane, and another supervisor normally assigned to the flight line but who was to supervise the work on N33701, discussed bringing N33701 into the hangar. [There were two supervisors on the second shift. One supervisor was normally assigned to the flight line, but he took charge of the maintenance on N33701. The second supervisor was in charge of a C check on another airplane.]

2100: The supervisor who took charge of N33701 told a second shift mechanic to remove both deice boots from N33701.

2130: N33701 was brought into the hangar by the second shift supervisor, who was responsible for the C check on another airplane. A second shift inspector informed the other second shift supervisor, who was now responsible for N33701, that he would volunteer to assist mechanics with the boot changes.

2145: A third shift flight line supervisor arrived at the hangar and noted that the third shift hangar supervisor was already there.

2200: The second shift supervisor responsible for N33701 observed two mechanics and the second shift inspector kneeling on the right stabilizer removing the right boot.

The third shift hangar supervisor observed the second shift inspector lying on the left stabilizer and observed two mechanics removing the right deice boot.

The third shift supervisor, who was working the hangar, asked the second shift supervisor (who was responsible for the C check on another airplane) if work had started on the left stabilizer. The third shift supervisor observed the supervisor look up at the tail of N33701 and state "No."

The third shift supervisor, who was working the hangar, told the second shift supervisor (who was responsible for the C check on another airplane) that he would be able to change the right deice boot that evening, that the left deice boot change could be made on another night, and that he would return the left replacement boot to stock. The second shift supervisor took the right replacement boot and placed it on a work bench.

2205: The third shift inspector arrived early for work and saw that the majority of the right deice boot had been removed. He reviewed the inspector's turnover form and found no writeup on N33701 because the second shift inspector, who had removed the upper screws, had not yet made his log entries.

2215: A third shift mechanic clocked in and went to the break room to chat with friends until the start of his shift at 2230.

Shift Change

2230: The second shift inspector, who removed the upper screws from the leading edges of both stabilizers on N33701, filled out the inspector's turnover form with the entry, "helped the mechanic remove the deice boots." He then clocked out, and left for home. The inspector later stated that he placed the screws that he removed from the top row of the left and right sides of the horizontal stabilizer in a bag and that he left the bag on the manlift.

One of the two mechanics, who was helping with the boot change on N33701, stopped working and returned to airplane 724 to finish work that he had started earlier in the shift.

A third shift mechanic was informed by the third shift supervisor that he was assigned to do the line check on N33701, and that he needed to reposition N33701 outside the hangar. N33701 was then moved outside the hanger.

The second shift mechanic, who had been removing the deice boot on N33701, gave a verbal turnover to the second shift supervisor (who was responsible for the C check on another airplane). The mechanic was instructed by the supervisor to give his turnover to a third shift mechanic. After giving a turnover to a third shift mechanic, the second shift mechanic locked up his tools and clocked out.

The third shift mechanic, who received the turnover from the second shift mechanic, was not assigned later to N33701. He later stated that he recalled seeing the bag of removed screws on the manlift. The third shift mechanic gave a verbal turnover to another third shift mechanic, who later did not recall receiving a turnover and stated that he did not see any bagged screws.

Another third shift mechanic arrived at the hangar and was informed by the third shift supervisor, who was working the hangar, that he was assigned to N33701's boot replacement and that he should talk to the second shift supervisor to find out what had been accomplished. There was no discussion regarding which of the two second shift supervisors that the third shift mechanic should talk to. The mechanic talked to the second shift supervisor in charge of the C check on another airplane.

The third shift mechanic then asked the second shift supervisor (who was responsible for the C check on another airplane) what had been done on N33701 during the second shift. The mechanic observed the supervisor point to the tail of N33701 and say that a few stripped screws had prevented the second shift mechanics from removing the right leading edge. The mechanic then asked if any work had been performed on the left deice boot. The supervisor informed him that he did not think he would have time to change the left deice boot that evening.

2245: The third shift line supervisor left the hangar to work at the gate and had no involvement with N33701.

2300: The second shift supervisor responsible for N33701 left work about this time. He had not talked to the other second shift supervisor, the third shift supervisor, who was working the hangar, or the third shift supervisor in charge of line checks before he left for home.

2330: The second shift mechanic who helped with the removal of the right boot clocked out and left for the evening.

Subsequently, the airplane was cleared for flight. The first flight was a passenger flight from IAH to LRD at 0700. There is no evidence from the morning's preflight that the flightcrew knew of any of the work performed on the horizontal stabilizer. Moreover, the FARs and airlines did not require them to be informed of such work.

The flight from IAH to LRD was without incident. Shortly after the accident, a passenger, who had been on the flight from IAH to LRD, informed Safety Board investigators that he was awakened on the flight to LRD by vibrations that rattled his beverage can on the meal tray in front of him. Accordingly, he asked the flight attendant if he could move to another seat. The passenger did not inform the flight attendant or any other crewmembers about the vibrations. Others passengers on that flight, some of whom had flown on that model airplane previously, did not recall unusual vibrations. The accident took place on the return trip from LRD to IAH.

1.17.4 Required Inspection Items (RIIs)

Continental Express' GMM 1 Section 5, states that "Continental Express has established a list of items that requires a concentrated inspection (RII) on any work performed on those items. This list includes items that could result in a failure or malfunction that could endanger the safe operation of the aircraft, if not properly installed or if improper parts or materials are used." On page 5-5, Paragraph 2, "Designated [required inspection] Items" the item "Stabilizers" is listed. Also, 14 CFR 135.427 states "A designation of the items of maintenance and alteration that must be inspected (required inspections) including at least those that could result in a failure, malfunction, or defect endangering the safe operation of the aircraft, if not performed properly or if improper parts or materials are used."

Continental Express' management and quality control inspectors stated that the removal and replacement of the horizontal stabilizer leading edge deice boots were not RIIs. RIIs are required to be inspected by a quality assurance inspector. However, the M-602 maintenance work order cards, used the night before the accident to assign the work to change both the left and right horizontal stabilizer deice boots, had the RII "Yes" block circled. Further, the completion of the deice boot change, the removal of the used deice boot, and the bonding of a new boot to the right side leading edge assembly were signed off by a quality control inspector on the third shift. However, the inspector stated that he knew that the boot was not an RII and therefore conducted only a cursory walk around the tail without inspecting the final installation of the leading edge/deice boot.

Embraer stated that the deice boots and leading edges, as assemblies, were RIIs and were part of the larger stabilizer assembly, listed in the FAA-approved operator's GMM as an RII. The manufacturer noted by letter (See appendix G) that the subject assembly met the operational requirement of the FAA for a RII, in accordance with 14 CFR 135.427(b)(2).

Continental Express' management maintained that the leading edge/deice boot assembly was a separate assembly and that if the manufacturer or FAA had wanted the assembly treated as an RII or critical item they should have made that clear.

1.17.5 Right Elevator Replacement

The maintenance records for N33701 revealed that on April 24, 1991, the right elevator was removed from airplane 708 because of damage from a lightning strike. Airplane 708 was subsequently returned to service following the installation of a replacement right elevator. The damaged elevator was repaired on April 27, 1991, and was installed on N33701 on May 2, 1991. The elevator had been repaired using approved technical information supplied by Embraer's Structural Repair Manual (SRM), section 55-20-01. The SRM referred the mechanic to section 51-62-01 of the SRM, which contained procedures for statically balancing the elevator, after the repair had been made. The mechanic who balanced the elevator following its repair stated that he had read the balancing procedures contained in the SRM.

SRM sections entitled "Control Surface Static Balancing" and "Equipment and Consumable Material for Balancing" had complete descriptions of control surface static balancing, a table of equipment used for control surface balancing, a balancing stand with an adjustable support, and included the Ground Service Equipment (GSE) Number 094 and a diagram of the necessary equipment.

The investigation revealed that the approved balancing equipment was available but apparently misplaced and was not used for the balancing of the elevator that was eventually installed on N33701. The mechanic stated that he used "homemade" balancing blocks on a level table and visually confirmed the balance of the elevator. Embraer stated that it recommends the use of the equipment listed in the SRM for balancing control surfaces; however, in emergency situations, jack assemblies could be used, provided that the rotational axis of the control surface is horizontal. The FAA's Principal Maintenance Inspector (PMI) assigned to Embraer was asked by accident investigators if the procedure used by the mechanic was approved by the FAA, and he replied "No."

Embraer was asked what effects an unbalanced elevator would have on the airplane. Embraer replied that the repair to the right elevator on the accident airplane would "represent [a] less than 1% out of balance condition, which could be regarded as a negligible effect."

1.17.6 No. 1 Engine Overtorque

On September 25, 1990, the left engine and propeller on N33701 experienced an overtorque to 141 percent. After performing the required initial inspection of the engine, per the Pratt & Whitney Maintenance Manual 72-00-00, Revision 6, the airplane was issued a ferry permit to return to Houston for further detailed inspection. As a result of the overtorque, the left propeller was changed on September 28, 1990, per the Hamilton Standard Maintenance Manual. The engine was inspected in accordance with Pratt & Whitney Canada Service Information Letter PW- 123, issued on March 9, 1990. On September 28, 1990, the airplane was returned to service.

The Pratt & Whitney maintenance manual required, in addition to the initial inspection, the following: repetitive inspections of the chip detector/filter element after approximately 10 hours or 1 day of operation, and thereafter at approximately 25 hours, 50 hours, and 100 hours, respectively, with the last check at approximately 250 hours or at the next A check. If no ferrous material was found after these checks, the engine could remain in service without further special maintenance action and subject to local airworthiness authority approval.

The review of the maintenance records revealed that certain procedures recommended by the Pratt & Whitney maintenance manual were not followed. For example, there was no record that the required repetitive chip detector inspections were performed. Continental Express stated that it had performed a continuity check of the chip detector circuit at every line check, which occurs less frequently than every 2 days (about 175 times in the past · year). Continental Express added that the line check method would have detected the presence of metal in the detector. There were no reports of chip detector problems during that period. Continental Express also stated that it had performed eight A checks during the same time period, in which the engine scavenge and main filters are checked. There was no record of metal particle contamination.

Additionally, the required engine log book entry regarding the overtorque event was not found. Also, there was no record that the PMI had been requested to provide or had granted the required approval for the engine to remain in service, although Continental Express had notified the PMI of the event.