出國報告(出國類別：其他)

參加新加坡民航學院「Aviation Weather Risk Management」訓練視訊報告

服務機關：交通部民用航空局飛航服務總臺
姓名職稱：于守良 課長
莊清堯 主任氣象員
郭力瑋 預報員
派赴國家：臺灣，中華民國
出國期間：民國 110 年 9 月 20 日~ 9 月 24 日
報告日期：民國 110 年 11 月 01 日

提要表

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<tr><td>視訊辦理：</td><td>是</td></tr>
<tr><td>相關專案：</td><td>無</td></tr>
<tr><td>計畫名稱：</td><td>航空氣象現代化作業系統汰換及更新計畫-研習航空氣象天氣預報及劇烈天氣守視技術(視訊報告)</td></tr>
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<tr><td>于守良</td><td>交通部民用航空局</td><td>飛航服務總臺飛航業務室</td><td>課長</td><td>薦任(派)</td><td></td></tr>
<tr><td>莊清堯</td><td>交通部民用航空局</td><td>飛航服務總臺主任氣象員</td><td>主任氣象員</td><td>薦任(派)</td><td></td></tr>
<tr><td>郭力瑋</td><td>交通部民用航空局</td><td>飛航服務總臺臺北航空氣象中心</td><td>預報員</td><td>薦任(派)</td><td>聯絡人：
leokwo@anws.gov.tw</td></tr>
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<tr><td>前往地區：</td><td>臺灣，中華民國</td></tr>
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<tr><td>關鍵詞：</td><td>航空氣象，飛航天氣風險管理</td></tr>
<tr><td>報告書頁數：</td><td>45 頁</td></tr>
<tr><td>報告內容摘要：</td><td>受 COVID-19 疫情因素影響，原訂本(110)年本總臺至美國航空氣象中心研習航空氣象天氣預報及劇烈天氣守視技術，將延至明(111)年辦理，惟為使本總臺同仁持續透過訓練，瞭解國際間各項飛航天氣作業、服務及風險</td></tr>
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	管理方式，以提升臺北飛航情報區內機場、航路及區域之預報品質，改以視訊方式參加新加坡民航學院「Aviation Weather Risk Management」訓練。本計畫內容包含「安全管理系統」、「天氣對航空運營之影響」、「天氣風險管理系統及評估流程」、「當前天氣安全網介紹」、「案例分析」、「天氣決策」、「氣候學及天氣模式」、「以系統方法調查天氣事件」、「支持決策的主動預測系統」、「決策支持系統」、「天氣風險管理之改變及改善」及「訓練實作」等課程，並透過案例分析及討論，可使學員深入認識天氣風險管理，以提升本總臺航空氣象服務之品質。
電子全文檔：	C11000134_01.pdf
附件檔：	
限閱與否：	否
專責人員姓名：	林侑宣
專責人員電話：	02-23496193

目次

壹、目的

因飛航服務總臺現正推動航空氣象現代化作業系統汰換及更新計畫(AOAWS-RU)，該計畫主要目標在於進一步精進現行臺北飛航情報區內航空氣象系統、作業及服務等面向之效率及品質，其中美國在氣象預報技術的領域，一直佔有國際前趨的地位，為了解目前最新的航空氣象預報技術及航空氣象資訊系統發展情況，飛航服務總臺臺北航空氣象中心將選派氣象預報員前往隸屬於美國國家氣象局的航空氣象中心（Aviation Weather Center，AWC）參訪研習，透過與先進國家研習交流，除提升預報員的專業能力和航空氣象預報的品質外，進而以學習到的國際視野，進一步協助 AOAWS-RU 計畫進行，使計畫成果與國際接軌。

惟因新冠肺炎(COVID-19)疫情自 2019 年起陸續在世界各國爆發，因美國之邊境管制政策及美國聯邦航空總署(FAA)之外部人員參訪限制等因素，而無法依原訂計畫赴 AWC 進行訓練。然為使飛航服務總臺航空氣象同仁能夠在疫情影響下，了解國際間各項飛航天氣作業、服務有關之航空氣象風險管理方式，以持續提升臺北飛航情報區內機場、航路及區域之預報品質，故改以視訊方式參加新加坡民航學院「Aviation Weather Risk Management」訓練。本課程內容包含「安全管理系統」、「天氣對航空運營之影響」、「天氣風險管理系統及評估流程」、「當前天氣安全網介紹」、「案例分析」、「天氣決策」、「氣候學及天氣模式」、「以系統方法調查天氣事件」、「支持決策的主動預測系統」、「決策支持系統」、「天氣風險管理之改變及改善」及「訓練實作」等課程，並透過案例分析及討論，可使學員深入認識天氣風險管理，以提升本總臺航空氣象服務之品質。

貳、 過程

一、日期：於 110 年 9 月 20 日至 110 年 9 月 24 日期間全程以視訊方式參訓。

二、授課講師：

(一)Mr. MICHAEL DOIRON 現任新加坡民航學院專任 CRM 及 SMS 相關課程客座講師、加拿大直升機飛航安全專案執行官， CIRRUS 飛航安全服務總裁。於 2006-2013 年間曾任美國洛杉磯 、加拿大、巴基斯坦、烏干達、肯亞、盧安達、安曼、布拉格、馬德里、布魯塞爾、巴黎等至少 20 國 40 個地區的 SMS 領隊及執行官或負責該區的 SMS 教育訓練，並於 2013 年榮獲 Torrance Awards Safety Consultants & Training 獎項之殊榮，對航空氣象風險 SMS 之累積經驗由此可見一斑。

(二)Mr. JOHN DUCHER，人為因素及氣象諮詢專家，擁有加拿大飛行及簽派員執照，屬 AMS(American Meteorological Society；美國氣象協會)及 AMOS(Australian Meteorological and Oceanographic Society；澳洲氣象及海洋協會)會員。

三、參加人員：

(一)飛航業務室航空氣象課于守良課長

(二)臺北航空氣象中心莊清堯主任氣象員

(三)臺北航空氣象中心郭力瑋預報員

四、課程內容(如下表)：

(一)第 1 天(20 Sep.2021)

時間	課程內容
1300~1400	Introduction to Safety Management Systems (SMS)
1415~1515	Impact of Weather on Aviation Operations
1530~1630	Climate Change Impacts
1645~1800	Overview of Weather Risk Management Systems

(二)第 2 天(21 Sep.2021)

時間	課程內容
1300~1400	Systems View of Accident Causation
1415~1515	Overview of Current Weather Safety Nets
1530~1630	Case Study/Exercises
1645~1800	Weather Decision Making

(三)第 3 天(22 Sep.2021)

時間	課程內容
1300~1400	Weather Risk Management Process
1415~1515	Weather Risk Assessment - Exercise
1530~1630	Weather Risk Control / Treatment
1645~1800	Weather Risk Control / Treatment - Exercise

(四)第 4 天(23 Sep.2021)

時間	課程內容
1300~1400	Climatology and Weather Patterns
1415~1515	Climatology and Weather Patterns
1530~1630	Investigation of Weather Occurrences
1645~1800	Investigation of Weather Occurrences

(五)第 5 天(24 Sep.2021)

時間	課程內容
1300~1400	Case Study
1415~1515	Proactive Forecasting Systems for Supporting Decision Making
1530~1630	Driving Change & Improvement - Doing Something About Weather
1645~1800	Certificates Presentation and Closing

參、課程內容摘要及實作

一、 天氣對航空運營之影響（Impact of Weather on Aviation Operations）

國際航空運輸協會（以下簡稱 IATA）安全報告分析中指出 2016-2020 年，與天氣因素相關的飛安事故率為 37%，飛安事件不僅造成直接經濟成本損失，還有間接經濟成本損失。依據 IATA 統計，飛安事件每年對全美航空業者造成的直接經濟成本約 65 億美元。美國聯邦航空總署（FAA CDM）報告指出，在美國 40%的飛安事件與亂流有關，其造成之經濟成本損失約 75 萬美元。

圖 1 為 IATA 統計 2016 年至 2020 年飛機意外事件與天氣現象相關比率，飛行中失去控制（Loss Of Control In Flight，下稱 LOC-I）、可控飛行下撞地（Controlled flight into terrain，下稱 CFIT）及衝偏出跑道（Runway Excursion）事件與風切、低能見度、雷暴等天氣現象有非常高的相關性。

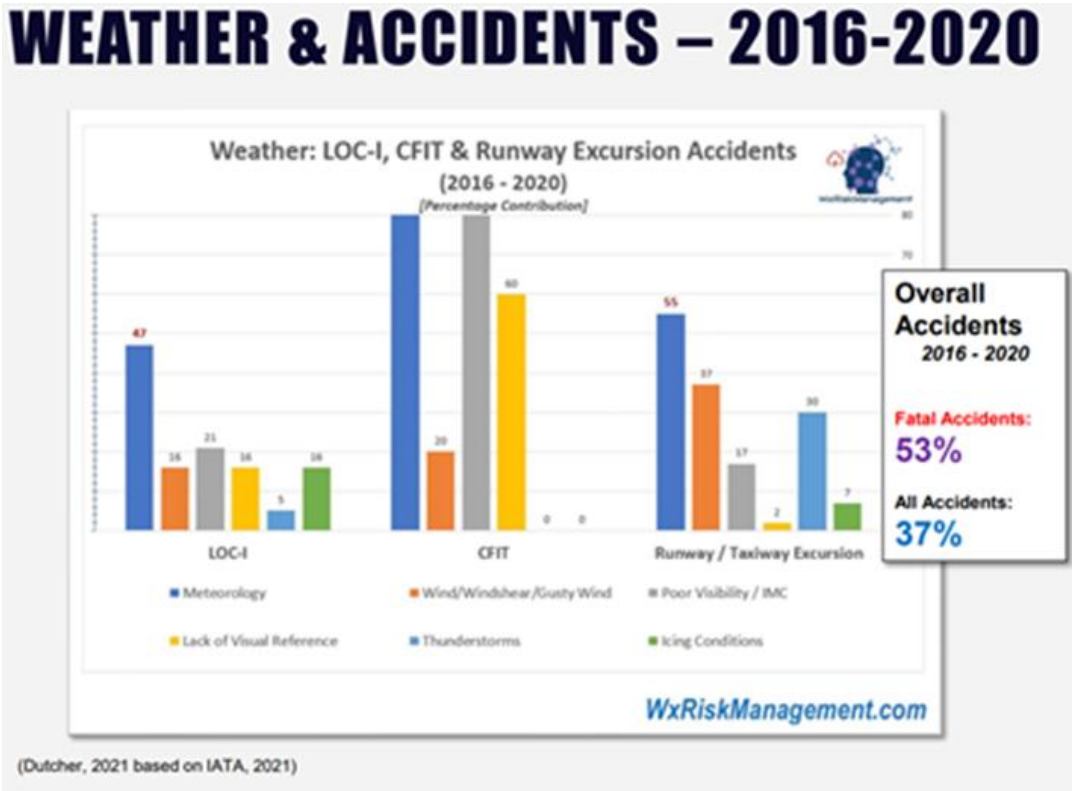


圖 1：飛機意外事件與各種天氣現象相關的比率

天氣對航空運營在經濟層面上影響巨大，我們必須採用更精準方式管理天氣風險，透過天氣風險管理流程，量化天氣危害造成的後果，進而採取適當的控制措施去降低風險，確實達成飛航安全之目的。

二、 天氣風險管理系統介紹（Overview of Weather Risk Management Systems）

參照國際民用航空組織第 9859 號文件（ICAO Doc 9859）安全管理手冊中安全管理系統（Safety Management System，下稱 SMS）之精神，建立天氣風險管理系統（Weather Risk Management System，下稱 WRMS）之架構。WRMS 四大面向為：天氣安全政策與目標、天氣安全保證、天氣安全風險管理、天氣安全推廣，各面相詳細內容如圖 2 所示。WRMS 的好處包含，以降低風險為最重要的目的去設計及改善天氣服務產品。舉例來說，因為具備判斷飛機誤點的發生性高低，如此便能夠幫助航空公司避免經濟成本損失，改善整個系統在安全上的表現。天氣風險管理系統之精神必須由最高階管理層至一線員工，從上至下貫徹執行，了解且願意負起安全責任。

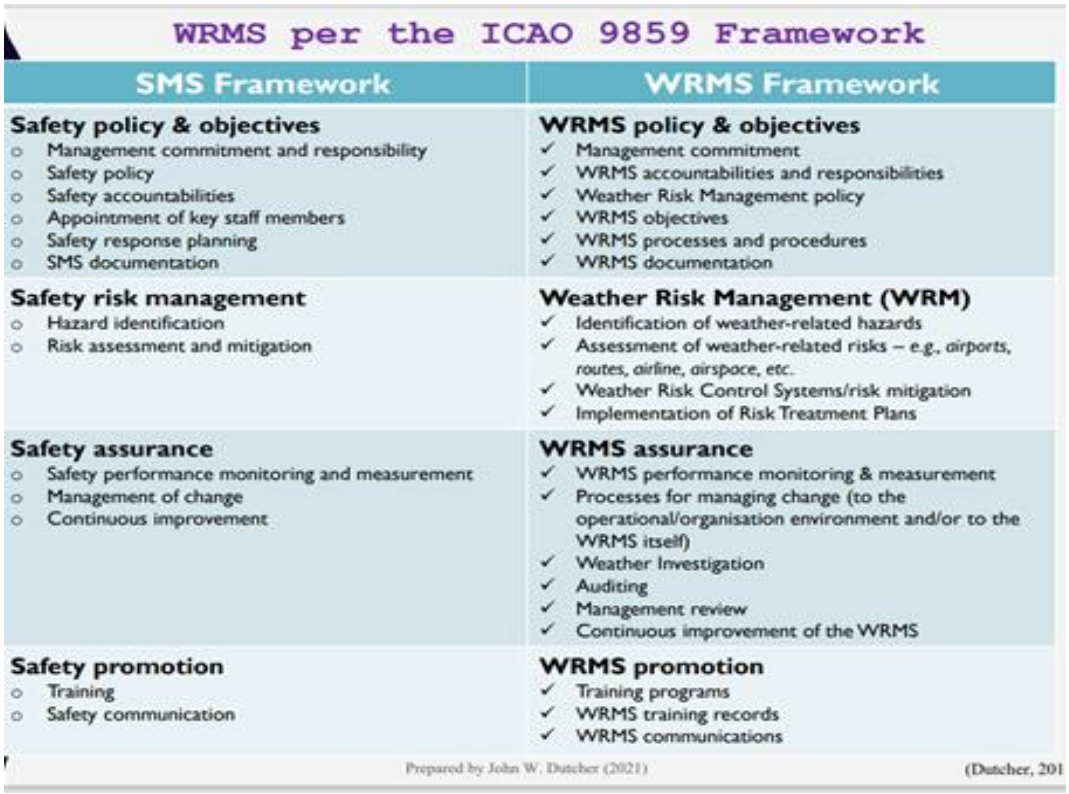


圖 2：天氣風險管理系統政策、目標、風險管理、保證及推廣

三、 當前天氣安全網介紹（Overview of Current Weather Safety Nets）

當前天氣安全網之航空氣象產品非常完整，包含機場例行天氣報告(METAR)、機場特別天氣報告(SPECI)、機場天氣預報（TAF）、航機報告（AIREP/PIREP）、顯著天氣圖（SIGWX）、顯著危害天氣報告（SIGMET）、低空危害天氣報告（AIRMET），低空風切警報（LLWS Warning）。ICAO 和世界氣象組織（WMO）建立全球預報系統（WAFS），當前有 2 個世界區域預報中心，倫敦及華盛頓，提供全球高空風溫預報及顯著天氣預報。除此之外，還有熱帶氣旋預警中心（TCWC）、火山灰預警中心及太空天氣中心。氣象服務必須有好的品質管理才能保障飛航安全，因此 ICAO 及 WMO 要求世界氣象服務必須實施品質管理系統，以符合 ISO 9001 標準。

四、 案例分析：法國航空 447 號（Case Study，Air France 447）

2009 年 5 月 31 日，該航班原訂由巴西里約熱內盧加利昂機場（SBGL）飛往法國巴黎戴高樂機場（LFPG），機型為空中巴士 A330 客機，載有 216 名乘客及 12 名機組人員。2009 年 6 月 1 日 2 時 14 分，AF447 於 TASIL 航路點墜毀，此航路點位於大西洋。飛機失事前正飛越赤道熱帶輻和區，氣象分析顯示飛行路徑附近有中尺度對流系統，失事前一小時遇到輕度亂流。機長離開駕駛艙前往休息時，沒有將詳細天氣狀況告知副駕駛。造成飛機失事原因為皮托管（pitot tube）結冰而失效，無法正常偵測飛機速度，飛機解除自動駕駛模式，機組員操作錯誤導致失速，最後造成空難。

課堂練習之問題及答案：

(一) 機組員取得之天氣資訊有哪些？顯著天氣預報圖、高空風溫圖、高空亂流資訊、機場天氣資訊及機場預報。

(二) 機組員可用那些工具來評估天氣？顯著天氣預報圖及機場預報。

(三) 提供給機組員之天氣資訊是否符合國際民用航空公約第 3 號附約（ICAO Annex 3）之規定？沒有完全符合 ICAO Annex 3 之規定，像是缺少雷達及衛星資訊，以及飛機通信定址與報告系統（ACARS）應該要更新顯著天氣預報圖。

(四) 描述機組員於航機上如何使用顯著天氣圖？可以用顯著天氣圖去找出雷暴系統位置，計畫航路路線去避開雷暴系統。

(五) 什麼天氣資訊可以有效幫助機組員了解天氣資訊？衛星及雷達資訊可以協助機組員了解雷暴系統位置及強度。

AF447 案例顯示天氣資訊更新之重要性，若機組員有即時衛星及雷達資訊，可以知道雷暴系統強度及位置，即可選擇其他航路路線去避開雷暴系統，進而避免飛機進入雷暴系統，遇到亂流及積冰，導致皮托管失效。怎麼建構一個更安全的天氣服務網是不可或缺的事，天氣資訊品質除了正確性很重要以外，即時性亦非常重要，天氣服務的難題就是要同時兼顧正確性及即時性，如何解決就需要透過安全管理系統來量化每一項風險的風險指數，來協助氣象作業人員作出適合的判斷及動作。

五、 天氣決策（Weather Decision Making）

造成失事之因素，造成飛航意外事件原因為系統失敗，透過 SMS 這項工具去預防飛安事件發生。從圖 3 可以發現意外事件發生與人為因素有關，但一個意外事件發生不僅僅是單一錯誤造成，而是整個系統存在許多錯誤，因此對整個系統做全面檢視，才能找出隱藏其中的危害。

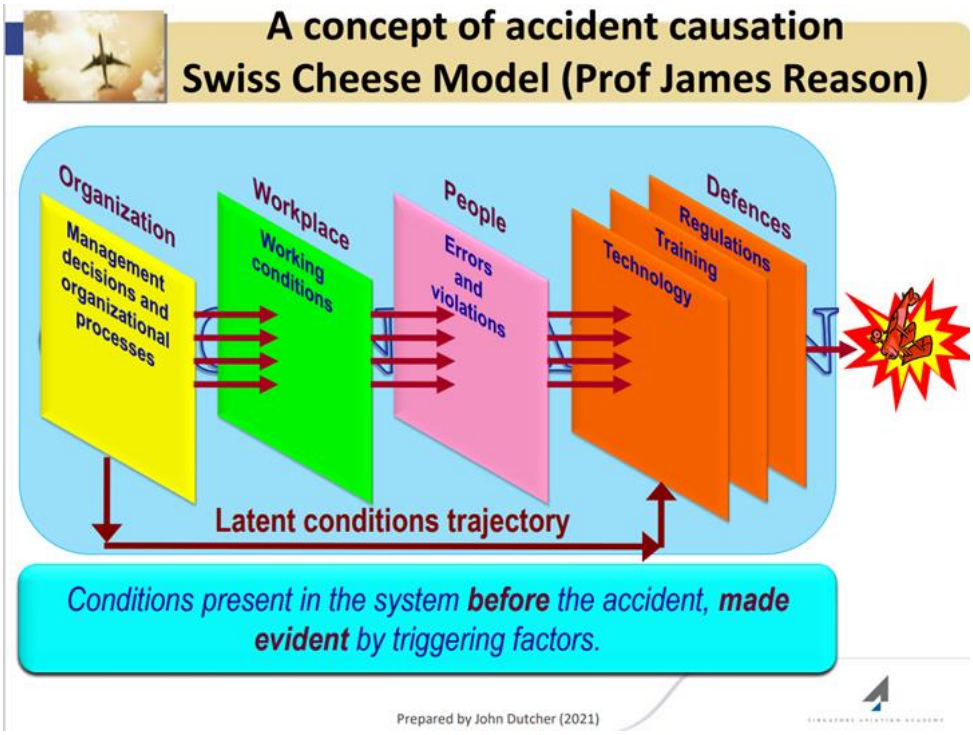


圖 3：瑞士乳酪理論

天氣決策，影響決策之因素包含時間、不正確或模擬兩可資訊、壓力、受到階級壓力。自然主義決策框架考慮動態操作環境之影響因素。美國國家運輸安全委員會（NTSB）研究從 1991 年到 2000 年 19 個飛安事件案例，報告指出主要原因為機組員疏失，其中 47%為持續計畫偏見（Plan Continuation Error，下稱 PCE）影響飛行決策，進而造成飛安事件。PCE 指的是，在狀況已經改變的情況下，機組員會持續進行原本的計畫。在航機起飛及降落時，PCE 為主要發生之人為錯誤，特別常見於專業且經驗豐富之機組員。機組員的決策比動作來得相對重要，根據 NTSB 於 1994 年研究指出決策對於造成飛安事件的貢獻大約佔 66%，其中約有 75%的飛安事件歸因於 PCE。舉例來說，氣象預報機場附近有雷暴系統，機組員可以選擇轉降至其他機場或是重飛，但當前面航班成功降落後，即使雷暴系統非常靠近機場，機組員可能會選擇繼續進場，因為機組員選擇相信前面航班遇到的天氣情況與自己一致，而不會仔細審視天氣情況是否不適合繼續執行降落。

六、 天氣風險管理流程（Weather Risk Management Process）

天氣風險管理流程可視為結合風險評估及風險控制，加上定期追蹤及更新，如圖 4 所示。流程分為 5 步驟，第 1 步為建立事件起因，第 2 步為危害識別，第 3 步為進行風險分析，第 4 步為風險評估，第 5 步為風險控制改善措施。在確認危害之後，藉由評估危害造成的嚴重程度和發生可能性，來評估危害所導致的風險是否可被接受，若無法接受則應採取相關措施以降低至可接受之程度。以下進一步說明這 5 個步驟；

圖 4：天氣風險管理流程圖

(一) 建立事件起因（Establish the Context），界定風險管理應考量的外部和內部因素，並設定風險管理政策適用範圍和判定原則。透過圖 5 步驟可以清楚地指出造成風險的因素條件為何。舉例來說，任務目標是飛航安全，對於臺北航空氣象中心來說，最重要的因素就是天氣服務，利害關係人為飛航管制員、簽派員及機師，造成危害的因素就必須與天氣相關，假如考慮位置造成的危害，可能是地形因素產生危害天氣進而造成飛安事件。

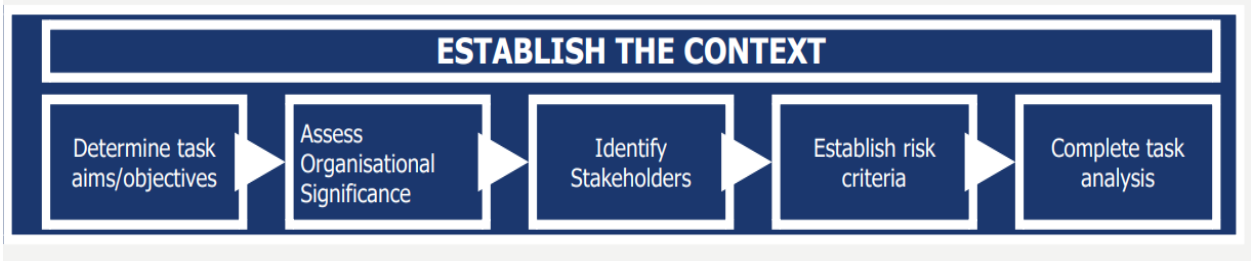


圖 5：建立事件起因流程圖

(二) 危害識別：危害是可能造成損害或傷害的事件或情況；風險則是危害可能產生損害或傷害的機會。這個步驟最重要的事決定需要被管理的風險。什麼樣的風險可能發生?列下所有可能的風險。如何發生?考慮可能發生之情境。為什麼會發生?考慮可能造成的原因。什麼風險會造成目標重大傷害，目標可考慮設備人員和環境。舉例來說，低空風切會造成航機及機上人員重大傷害，所以低空風切是一種危害。

(三) 進行風險分析，重要性在於了解風險的可接受程度為何。透過對風險分級，去決定適當的風險控制策略。此步驟需評估出現危害後果之可能性及危害造成後果之影響程度，可能性及影響程度都是建立在現有的控制措施下去做評估，透過可能性及影響程度這 2 個量化指標來決定風險等級，利用風險等級來判斷這樣的風險是否可接收，若不能則必須採取行動去降低風險，並列出一系列的控制措施。舉例來說，當考慮改變作業程序造成的風險時，現有控制措施為教育訓練，因此在評估改變作業程序造成危害的可能性及影響程度，必須考慮教育訓練造成的影響。

評定可能性時，必須注意指的是危害造成後果的發生可能性，可參考歷史資料，並使用下列之風險發生可能性參考表，如圖 6 所示。數值 5 表示經常發生，其餘數值表示發生可能性依次遞減，數值 1 表示幾乎不會發生。

RISK PROBABILITY

Probability of Occurences		
Qualitative Definition	**Meaning**	**Value**
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur some times (Has occurred infrequently)	4
Remote	Unlikely, but possible to occur (Has occurred rarely)	3
Improbable	Very unlikely to occur (Not known has occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Note: ***It is the likelihood of the consequence being rated, not the likelihood of the hazard.***

圖 6：風險發生可能性對照表

評定影響程度時，可參考歷史資料，並使用下列之風險影響程度參考表，如圖 7 所示，字母 A 表示造成災難，即設備毀損或人員死亡，其餘字母代表造成的嚴重性依次遞減，字母 E 表示幾乎沒有影響。

ASSESSING CONSEQUENCE

Severity of occurrences		
Aviation Definition	***Meaning***	***Value***
Catastrophic	- Equipment destroyed - Multiple deaths	**A**
Hazardous	- A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely - Serious injury or death to a number of people. - Major equipment damage	**B**
Major	- A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency. - Serious incident. - Injury to persons.	**C**
Minor	- Nuisance / Operating limitations / Use of emergency procedures / Minor incident	**D**
Negligible	- Little consequences	**E**

Note: Rate the severity of consequences of the Worst Foreseeable Case Scenario ***in the absence of any additional corrective action*** **but** ***taking into account existing Controls and their effectiveness.***

圖 7：風險影響程度對照表

(四) 評估風險及可容忍度，利用風險接受度矩陣（Risk Acceptability Matrix），如圖 8 所示，以可能性及影響程度對危害進行風險評估後，可以得到風險等級，每一種風險等級對應到一個風險指數，然後決定這樣的風險指數是否可接受。如果不行，則必須採取適當的控制及緩解策略，只要風險指數達到 ALARP（As low as reasonably practical）標準即可，不需要將風險指數降至 0。ALARP，表示風險指數已被降低至合理值，經過成本效益分析，任何進一步降低風險的措施會導致成本負擔過重。

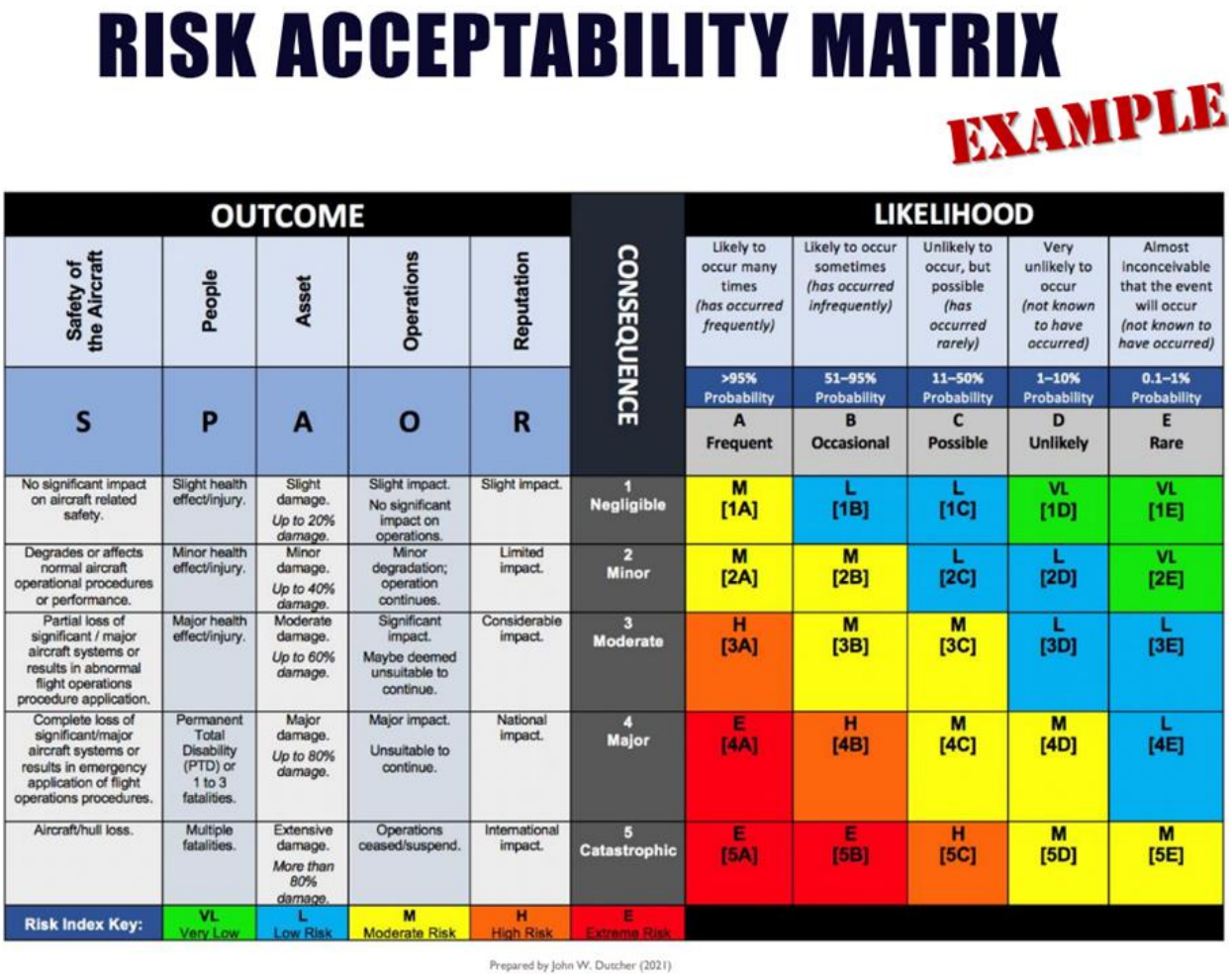


圖 8：風險接受度矩陣圖

藉由圖 9 對於不同風險指數之建議，即可決定是否採取控制及緩解措施，降低風險。風險指數為 5A、5B、4A 對應到的風險指數為極度危險，必須採取立

即停止作業或活動來降低風險。風險指數為 5C、4B、3A 對應到的風險指數為高度危險，必須確認風險分析已完成且已採取適當的控制措施。

Risk Level	Risk Index	Acceptability / Action Required
5A, 5B, 4A	Extreme Risk	**STOP OPERATION OR PROCESS IMMEDIATELY** Unacceptable under the existing circumstances. Do not permit any operation until sufficient control measures have been implemented to reduce the risk to an acceptable level. Senior management approval required.
5C, 4B, 3A	High Risk	**CAUTION** Ensure that risk assessment has been satisfactorily completed and declared preventive controls are in place. Senior management approval of risk assessment before commencement of the operation or process.
5E, 5D, 4D, 4C, 3C, 3B, 2B, 2A, 1A	Moderate Risk	Perform or review risk mitigation as necessary. Departmental approval of risk assessment.
4E, 3E, 3D, 2D, 2C, 1C, 1B	Low Risk	Risk mitigation or review is optional.
2E, 1E, 1D	Very Low Risk	Acceptable as is. No risk mitigation required.

圖 9：風險接受度分類表

(五) 風險控制及緩解，一共有 3 種方式，規避（Avoidance），取消作業或活動，減少（Reduction），減少作業或活動次數，或採取行動降低可接受風險結果的嚴重程度，隔離（Segregation of exposure），採取行動以隔絕危害後果的影響，或建構備援或防護系統。天氣風險控制與緩解措施，可透過安全防護機制，像是加強技術、訓練及法規等 3 項達成。舉例來說，美國國家大氣科學研究中心建立山岳波（Mountain Wave Forecasts）預報系統，即可提供有用的亂流資訊予航機，降低亂流對航機造成的危害，這就是透過加強技術去控制風險。

(六) 監督及評量，這是風險管理系統的一部分，透過這個機制可以持續改善風險管理系統。因為危害是動態性，像是改變環境會影響風險控制措施之需求，改變風險等級，也就是說控制措施不會永遠有效。訂定關鍵績效指標（Key Performance Indicator，KPI）目標值，去評量系統之效能及人員作

業效率。建立系統資料庫，包含下列事項，控制措施會造成什麼效果，有什麼新的風險需要去控制。

(七) 溝通及諮詢，在風險管理流程中需要時常進行溝通及諮詢，有助於增進作業人員對於風險及天氣風險管理流程的認識。確保利害關係人的各種觀點有被考慮到，確保所有人員清楚各自扮演的角色及責任。

以下是地面風切為例說明如何利用危害識別及風險評估控制表（Hazard Identification, Risk Assessment and Control；HIRAC）表格（如圖 10），去決定風險指數，由風險指數決定採取何種行動去降低風險，這是非常客觀的預防風險措施。

Operation/Business Activity being assessed:

No.	Hazard(s)	Consequence	Likelihood	Current Controls (based on Hierarchy of Control)	Initial Risk Rating	Further Recommended Control (based on Hierarchy of Control)	Revised Risk Rating
1	Strong Surface Tailwind (>10 KT) resulting runway overrun – high-speed	4 Major	B Occasional	Wind Sensor near centre of runway at MET enclosure. METAR/SPECI reporting. MET Updates to ATC. ATC Update ATIS for Pilots. Pilots have tailwind limit for aircraft. Pilots can conduct Go-Around. Airport/ATS ERP	4B High Risk	Wind Sensors at various locations at the airport (correct installation, calibration/maintenance) Change Runway Procedures Avoid Close Vectoring to Final MET and ATS Weather Refresher	4C Moderate Risk

圖 10：危害識別及風險評估控制表

七、 案例分析（Case Study）：以地面風切(大於 10KTS)造成航機衝出跑道作為危害因素

(一) 現有的控制措施有：

1. 在跑道中間設置風向風速計。
2. 機場例行天氣報告及機場特別天氣報告供應。
3. 當機場發生顯著天氣時，ATIS 系統能即時更新氣象資訊。
4. 機師在風切環境下對飛機之操作限制。
5. 機師重飛之執行能力。
6. 機場及飛航服務之資源規劃。

基於現有風險控制措施，地面風切造成之危害後果影響程度為 4，屬於重大，因為風切會導致航機失控進而造成重大損壞，對機上人員可造成殘疾。地面風切造成的危害發生可能性為 B，機率為 51-95%，因風切造成意外事件發生率大於 50%。因此初始風險指數為 4B，由安全風險矩陣評估為極度危險，必須採取行動去降低風險。

(二) 下列為建議之控制措施為：

1. 機場更多個位置安裝風向風速計。
2. 飛機換跑道程序。
3. 五邊降落時避免航機距離太過接近。
4. 氣象報文更新頻率增加，例如增設低空風切警報系統，可即時偵測機場跑道周邊亂流資訊，提供即時風切資訊予飛行員。

無論有沒有考慮建議之控制措施，地面風切造成之危害後果影響程度仍為4，屬於重大，沒有改變，因為控制措施不能改變飛機因風切失控造成的損害，但控制措施可使危害發生可能性降低。在考量建議之控制措施後，地面風切造成的危害發生可能性為 C，機率為 11-50%，顯著地下降，因此建議之控制措施可有效降低危害發生之可能性。

八、 氣候學和天氣模式（Climatology and Weather Patterns）

據統計結果，天氣是導致航空事故比例持續增加的主要原因，1967 年因天氣因素而發生航空事故之比例約為 40%，至 2010 年則成長至約 50%。其中以熱帶區域（南北緯 23.5 度之間）較易因為天氣因素發生航空事件（如圖 11）

Number of aircraft accidents and weather-caused aircraft accidents, 1967–2010

Zone	Latitude Range (°)	Main Features	All Accidents (Number)	Weather-caused Accidents (Percentage - %)
1	±12	ITCZ, Wind convergence area, deep convection	800	25
2	12 - 38	Subsidence, high-pressure areas	1330	50
3	38 - 64	Large-scale polar fronts, low-pressure areas	511	39
4	64 – 90 (Pole)	Polar regions	19	59

Tropics ranges from 23.5° North through 23.5° South.

Source: Multiple industry data cited in Mazon, *et al.* (2018). Influence of meteorological phenomena on worldwide aircraft accidents, 1967 – 2010. *Meteorol. Appl.* **25**: 236–245 (2018)

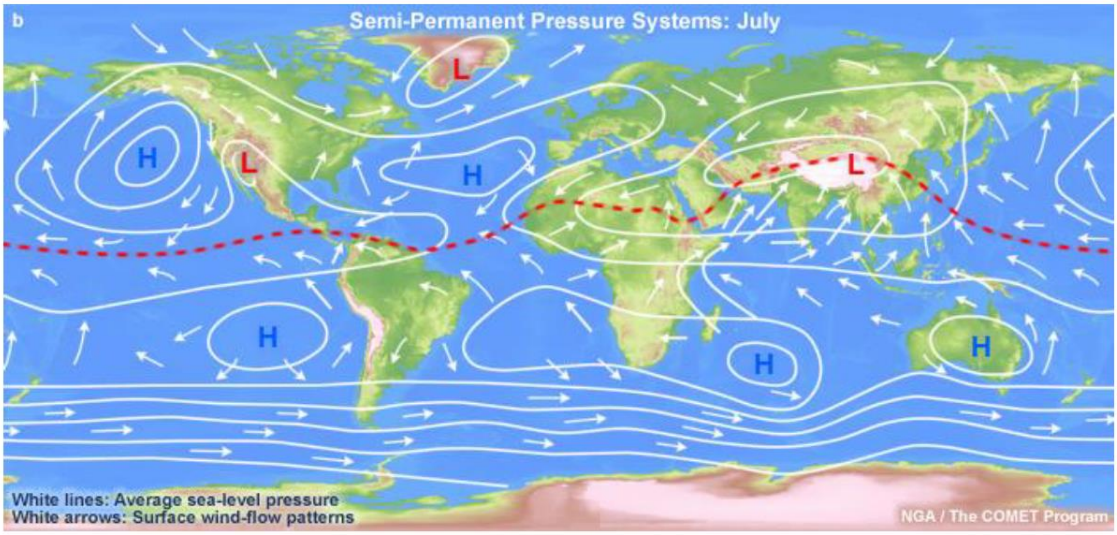
圖 11：天氣因素造成航空事件發生比率

因此，機場的地理位置將使其具有特別的季節性環境氣候而影響機場航班運作。以美國為例，因為美國地理氣候關係，機場航班於每年 1 至 7 月受氣候影響最為明顯。其主要因為熱帶地區有更多的時間受到太陽光直射的原因，當太陽光直射，地球表面容易因此加熱而帶動天氣變化，而中緯度區域因為太陽多斜射為主，地表多以較為廣泛的均勻受熱情況為主，故較不易發生快速且劇烈的天氣變化。因此與中緯度之氣候特性比較，熱帶地區的氣候多具有以下特性:較小的科氏力、無明顯的熱力梯度、容易發生局部性天氣、溫度及壓力具較小的日變化、依照降雨情況可為乾季及濕季，無明顯四季、較高的結冰高度及更多且活躍的雷雨活動。

常見於熱帶區域的天氣現象如下:

(一) 信風（TRADE WIND）

由於熱帶地區陽光強烈，終年炎熱，產生旺盛的上升氣流，形成赤道低壓帶，因此氣流到了高空後便開始往兩極擴散。而氣流到了南北緯 30 度時便開始沉降，形成亞熱帶高壓，此處空氣相當地乾燥，因為水氣在赤道附近隨著降雨流失。由於氣體是從高壓流向低壓，在高壓帶沉降的氣流便在低空流回赤道區，在北半球形成北風，在南半球形成南風，但受到科氏力的影響，氣流吹向西邊，才會造成北半球吹東北風、南半球吹東南風的情況(如圖 12)。



(Image: COMET Program / University Corporation for Atmospheric Research (UCAR)

圖 12：氣壓與風向示意圖

信風常將海洋溫暖而潮濕的空氣帶往陸地，使當地的氣候較為溫和：如亞熱帶濕潤氣候的夏半年雨量即來自信風帶來的水氣；中美洲、加勒比海諸島的東部雨量經常多於西部，也是因為信風的影響。信風減弱與聖嬰-南方振盪現象有關。

(二) 熱帶波動（TROPICAL WAVES）

大西洋中和周圍的東風波（也稱為東風波、熱帶東風波和非洲東風波）是一種大氣槽，是一個氣壓相對較低的細長區域，從北向南移動，從從東到西穿越熱帶地區，造成多雲和雷暴地區。在熱帶輻合帶（ITCZ）以北和以南

的副熱帶高壓脊或高氣壓帶的赤道側向東流動時形成熱帶波浪。熱帶波浪通常由沿赤道附近熱帶和亞熱帶的盛行東風向西攜帶。它們可能導致在北大西洋和東北太平洋形成熱帶氣旋。

在亞熱帶和熱帶地區，也可以從鋒區的尾端形成向西移動的波動，可以稱為東風波，但這些波浪不能正確地稱為東風波。它們是一種倒槽形式，具有東風波的許多特徵(如圖 13)。

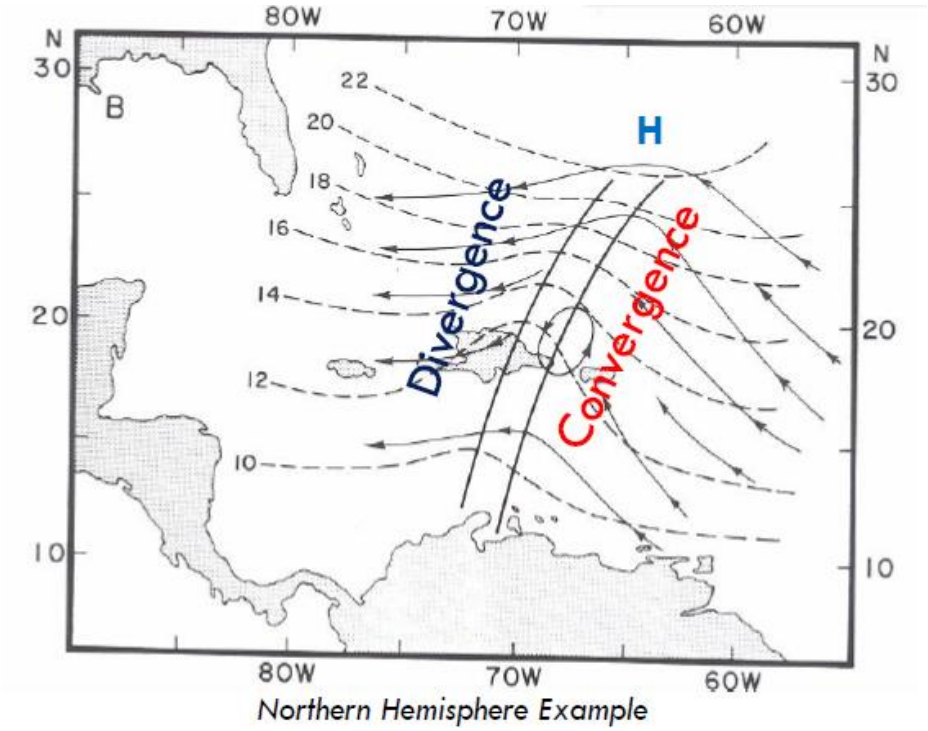


圖 13：北半球熱帶波動與輻合區示意圖

熱帶波動多伴隨有對流系統發展，對流位置需要看風場與高度間的變化關係，正常情況下，對流系統多發展於熱帶波動的波谷位置，但若風場隨高度增加而出現強勁的東風或西風時，對流系統也將因此移動到熱帶波動的西側或東側。而熱帶波動之對流系統也常帶來大範圍且強烈的降雨以及風場驟變的情況。

(三) 熱帶輻合帶（INTER TROPICAL CONVERGENCE ZONE (ITCZ)）

熱帶輻合帶（又譯間熱帶輻合區，縮寫：ITCZ），又稱為赤道低壓帶（又譯赤道低氣壓帶、赤道無風帶； Equatorial belt of calms）或赤道輻合帶，是活躍於赤道的低氣壓帶，南北半球副熱帶高壓帶間氣壓最低的風帶。其低氣壓的成因是太陽光一年兩次直射赤道，全年在回歸線之間移動，使赤道附近終年受熱，蒸發旺盛，導致空氣膨脹上升，大量的水氣逸散到大氣中，到高空向高緯度地區流動，導致近地氣壓降低而形成。因溫度水平分布較均勻，水平氣壓梯度力很小，風力微弱。又因上升氣流強盛，水氣充足的緣故，此區域多對流雨，一年有超過 200 天降雨。空氣上升至對流層後，分別向兩極移動，到了南北緯 30 度沉降，形成哈德里環流圈。

熱帶輻合帶是兩道信風相遇或季風槽之處，它的位置會隨著時間更動。陸地上，它會根據太陽黃道的位置在赤道南北面移動（如圖 14、圖 15）；海面上，受到季節影響的情形不明顯，而主要是受到海洋溫度變動的影響。有時會產生兩個熱帶輻合帶，一個在赤道以北，另一個在赤道以南，通常其中一個會較強烈，兩個區域之間就會發展出一個長高壓帶。前述發生於赤道以南之熱帶輻合帶稱為南太平洋輻合帶，是一個反向季風槽，是從海洋大陸的西太平洋暖池向東南向法屬波利尼西亞延伸的低層輻合、多雲和降水帶。

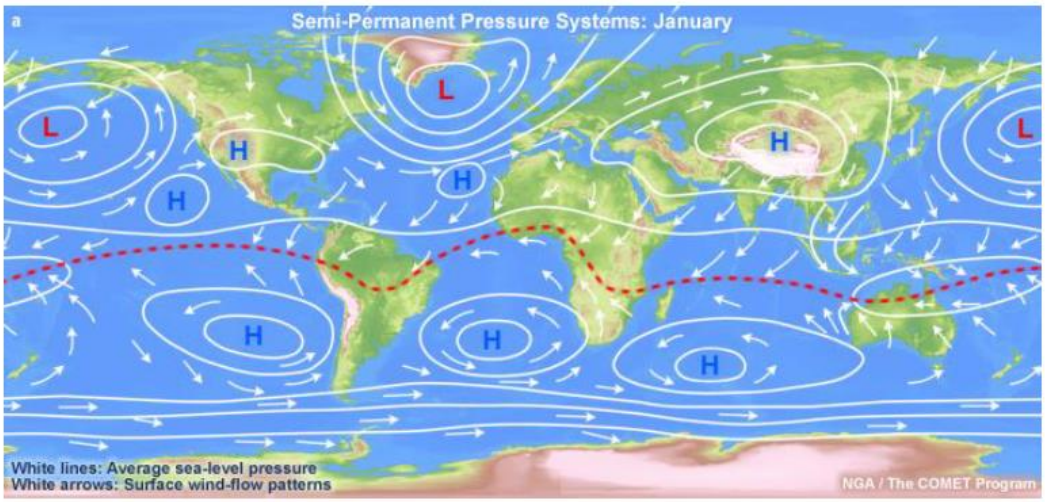


圖 14：1 月時熱帶輻合帶位置示意圖

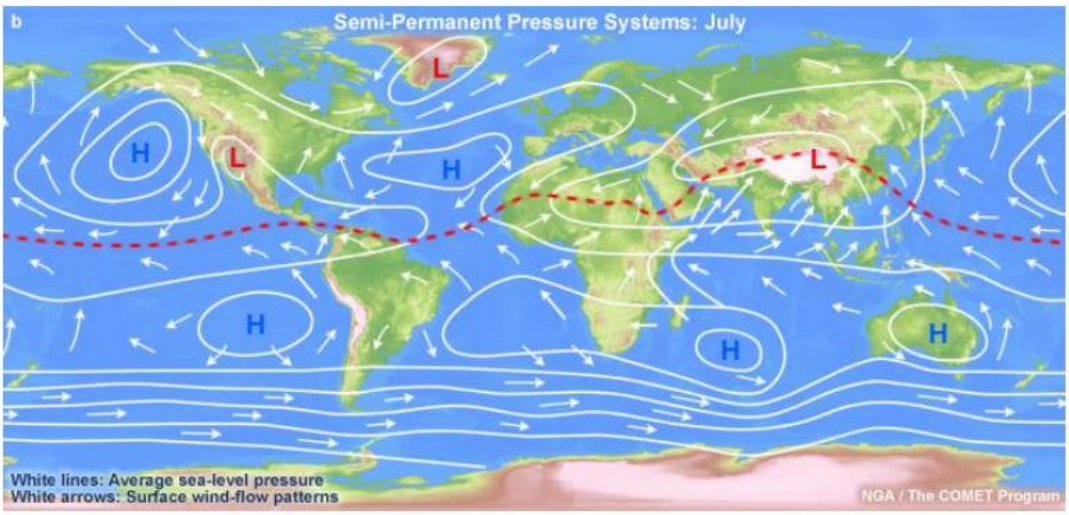


圖 15：6 月時熱帶輻合帶位置示意圖

熱帶輻合帶裡蒸發旺盛，有大量降雨，在南北移動的狀況下，造成熱帶地區只有乾濕兩季的分別，不像高緯地區有寒暖季節的分別。熱帶熱帶輻合帶多半有對流系統發生，故易有對流雲、閃電及強烈降雨等天氣現象。熱帶氣旋的形成需在低緯度的條件下，且熱帶輻合帶的低壓會造成風速和風向的變動，形成水平風切變。在南北球夏季時，若熱帶輻合帶遠離赤道超過 500 公里，柯氏力會增加熱帶氣旋形成的發生率。在北大西洋和東北太平洋地區，東風波會沿著熱帶輻合帶的邊界移動，導致雷暴的發生，在低垂直風切變的條件下，雷暴就會形成熱帶氣旋。

2009 年法國航空 447 號班機空難即因為通過 ITCZ，皮托管結冰而失效，無法偵測速度，加上機組員操作失誤所致。

(四)　季風

季風（又稱季候風）是週期性的風，隨著季節變化，並且盛行風向（40%以上風頻）季節切變達 120 度以上（按照傳統定義，非全球性季風定義）。主要發生在季風亞洲（東亞、東南亞、南亞地區）、西非幾內亞和澳大利亞的北部沿海地帶等地。北美、南美、阿拉伯半島及東南非亦有小範圍的季風現象，但未能形成大範圍且穩定的季風氣候帶。

阿拉伯人很早已發現了季風，並稱之為"موسم"（Mausim），意思為季節。古時代阿拉伯商人利用風向的季節變化特點從事航海活動，當時人們對盛行此地的季風已有一定的感性認識。17 世紀後期，隨著歐洲商人在這一地區航海活動的增加，人們對季風的觀察更為細緻，從而加深了對季風的認識。17 世紀後期愛德蒙·哈雷首先提出海陸間熱力環流的季風成因理論。隨著季風風向的轉變，雲雨等天氣現象也發生相應變化，因此季風與農業生產密切有關，從而引起廣泛關切。第二次世界大戰結束後，因為高空資料的積累，對季風的形成有更深刻的認識，提出季風是海陸分布、行星環流及地形三者的綜合影響。

季風的形成有以下兩種原因：

1．海陸熱力性質差異

海水的比熱容量遠比陸地為高，所以陸地在冬季時的降溫以及夏季時的升溫比海洋快和明顯，造成溫度上的差異。當空氣受熱膨脹，密度便會降低，因而向上升；反之亦然。這使得在夏季時陸地的氣壓會比海洋低，海洋的冷濕空氣向陸地移動，冬季時則相反，所以季風區在夏季和冬季的風向會相反。

2．行星風系季節移動

在赤道附近，以北半球為例，冬半年盛行東北信風，夏半年赤道低壓隨著太陽直射點北移而北偏，使得南半球的東南信風越過赤道，在北半球地轉偏向力的右偏作用下偏轉成西南方向的赤道西風。信風和赤道西風方向大致相反，從而形成季風。

東亞地區是世界上季風氣候最典型的地區，原因是該地地處世界上最大的大陸亞歐大陸和最大的海洋太平洋之間，海陸熱力性質差異造成的影響十分明顯。該地由此形成了獨特的熱帶季風氣候、副熱帶季風氣候和溫帶季風氣候。以下分就夏季及冬季季風進行說明：

1．夏季季風

東亞季風區範圍包括南海及太平洋西北沿岸地區，包含中南半島東岸、中國東部和朝鮮半島、菲律賓群島、日本等地。在北半球的夏季，南半球的大洋洲散熱明顯，成了一個冷源，氣壓比海洋高，季風氣流自東南向西北吹，進入北半球受科氏力影響偏轉為西南風，混合越過中南半島的南亞季風後在中國內陸的內陸熱低壓影響下轉而吹向中國內地，形成東南亞和南海夏季的西南季風。東面的太平洋因升溫比亞歐大陸慢，濕潤的空氣向亞洲的低壓移動，在東亞東部形成東南季風。這股氣流位於西北太平洋副熱帶高壓脊西側，並會和越赤氣流發展出季風槽。大部分西北太平洋的熱帶氣旋都是在季風槽中發展出來的。東亞季風跨越的緯度極廣，南至近赤道的檳城，北達副極地氣候的廟街（俄羅斯）、馬加丹，均為季風可到達的範圍。

除東亞季風區以外，另還有南亞季風區，其範圍包括北印度洋和孟加拉灣沿岸地區，包含印度次大陸和中南半島西岸。在北半球夏季，南半球的副熱帶高壓吹出之東南信風，在跨越赤道後受地轉偏向力影響轉為西南風（赤道西風）、加上索馬利亞的地形影響，成為強烈的西南氣流吹向印度次大陸。加上青藏高原受熱而在高空形成青藏高氣壓，加強該區的高空輻散，使南亞季風區的夏季季節風強而穩定，並有大量對流活動產生。因為地面吹著強勁的西風季節風，但高空卻受青藏高氣壓的東風急流影響，以致地面和高空風向不一致，或說垂直風切強烈，以致南亞季風區熱帶氣旋活動較少。

2．冬季季風

在冬季，西伯利亞平原以及蒙古高原成為一個強大的冷源，由於熱力性質的差異使氣壓上升，形成由東亞吹向太平洋和南半球的冬季季風。

綜合以上，南北半球冬夏兩季季風所至地面及高空風型態大致如圖16~19：

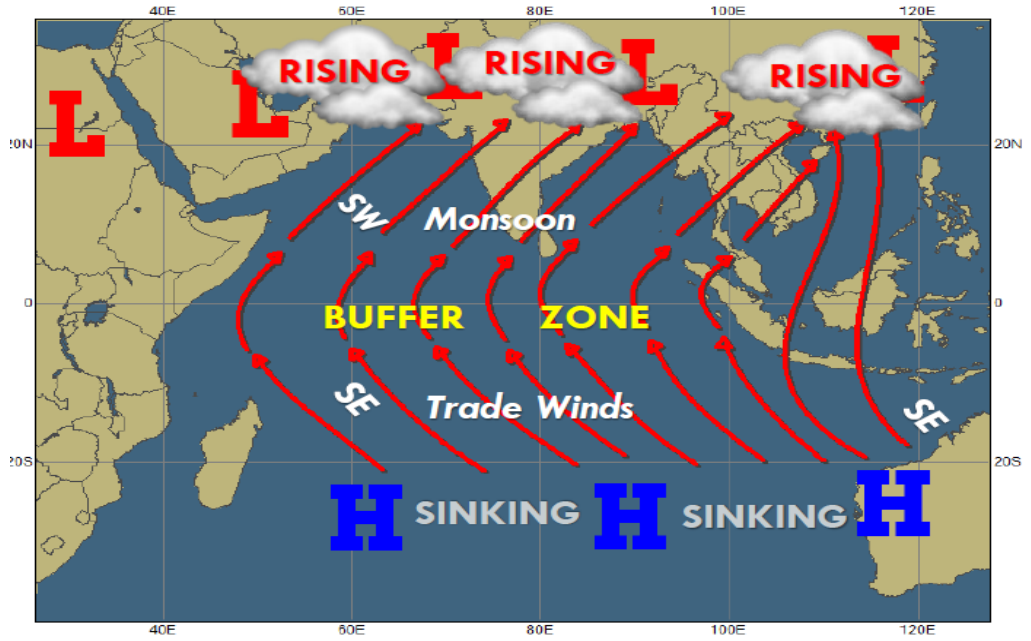


圖 16：北半球夏天（南半球冬天）季風之地面風型態

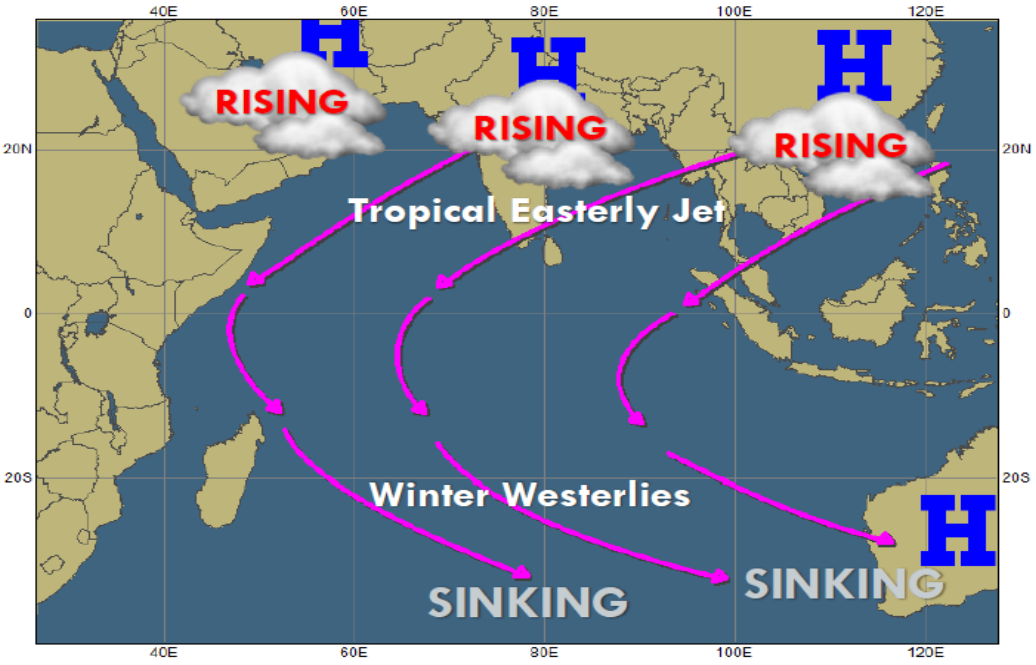


圖 17：北半球夏天（南半球冬天）季風之高空風型態

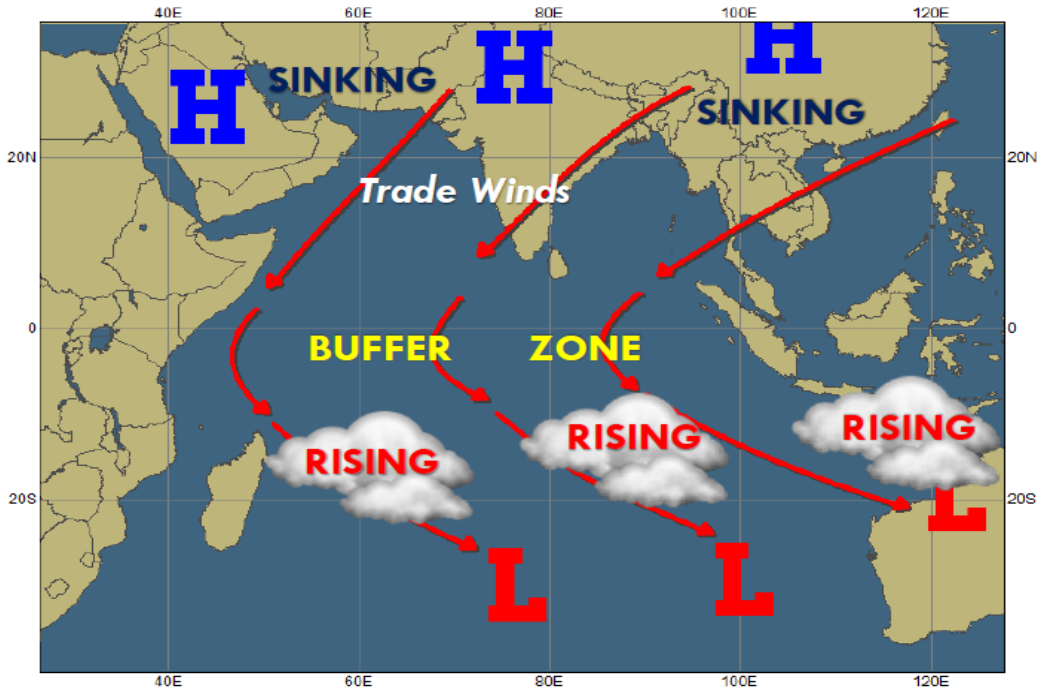


圖 18：北半球冬天（南半球夏天）季風之地面風型態

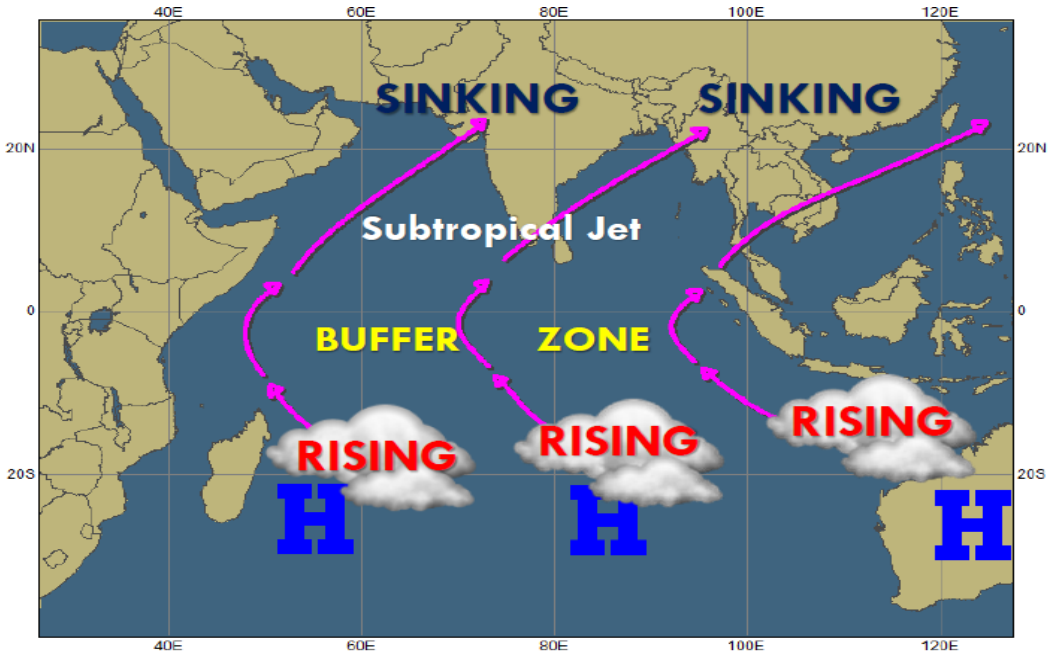


圖 19：北半球冬天（南半球夏天）季風之高空風型態

當臺灣處於東北季風期，一般 5 至 7 天會有一次冷鋒通過臺灣，使臺灣氣溫下降並會下雨，這種現象以臺灣北部及東北部為最普遍。臺灣西南部因位於中央山脈的西邊，東北風受地形阻擋，下雨機會遠較臺灣東北部為少。東北季風期間當有強烈的冷氣團影響，臺北的最低氣溫達 10℃以

下，我們稱為寒潮。高空中也較容易因為水氣降溫的原因，使航機遭遇積冰情況，2002 年復興航空 791 號班機事件即是經過調查確認係因積冰引起之飛航事件。

當臺灣處於西南季風時期，是西北太平洋地區颱風的最活躍期，颱風侵襲臺灣易造成風災、水災、沿海地區海水倒灌、及空氣中含鹽的強風所造成的鹽災（使作物及樹木枯萎）。如果來自南海的西南季風很強勁而潮濕，或者有明顯的合流現象都會使臺灣西南部地區發生豪大雨情況，而其引進之對流系統也對於飛行器及機場運作皆有嚴重的影響。

(五) 熱帶氣旋

熱帶氣旋泛指熱帶或亞熱帶水域上空的非鋒面天氣尺度低壓系統，具有有組織的對流（即雷暴活動）和明確的氣旋地表風環流。

熱帶氣旋的生成條件:

1. 溫暖的海洋（海面溫度，水深約 60m 的深度，大於攝氏 26 度）
2. 距赤道約 5 度緯度
3. 不強的垂直風切，如果垂直風切過強，熱帶氣旋對流的發展會被阻礙，使其正反饋機制未能啟動
4. 不穩定的環境
5. 大氣所含濕度高（20 至 25000 呎間）

熱帶氣旋對於飛航安全常見的災害如下:

1. 強陣風及危害側風
2. 低層風切、亂流與微爆氣流
3. 雷暴
4. 閃電和龍捲風
5. 大雨
6. 低能見度
7. 潮濕的跑道，
8. 機場周邊可能的洪水和山體滑坡

9．沿海機場可能遭遇到暴潮

就熱帶氣旋每年生成時間統計，西北太平洋全年皆有熱帶氣旋，但活動以一至二月最少，七月至九月最多（如圖 20）。北印度洋則主要集中在五月至十一月（如圖 21）。南半球的熱帶氣旋在十一月開始，至五月中左右結束，當中以二月中至三月初是高峰（如圖 22）。

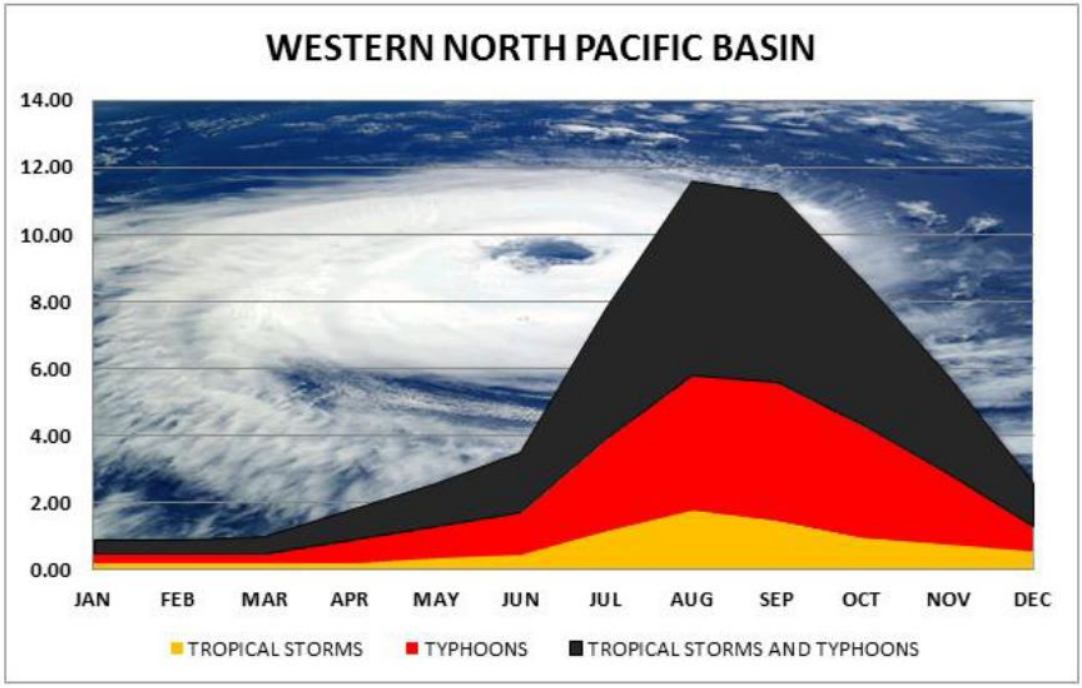


圖 20：西北太平洋熱帶氣旋生成時間統計

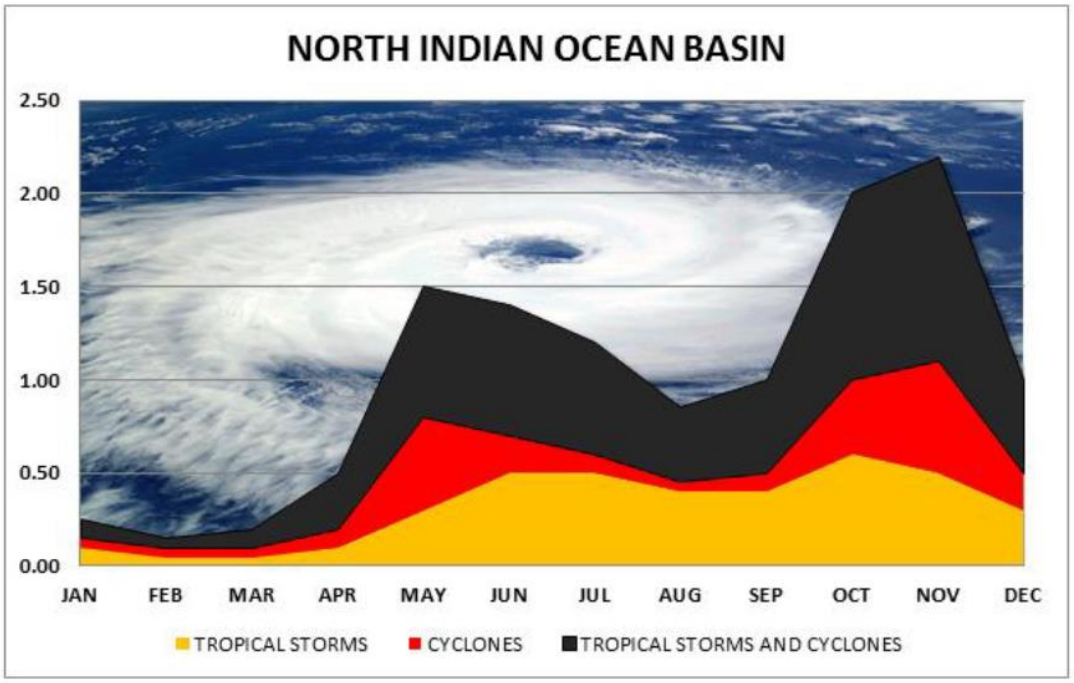


圖 21：北印度洋熱帶氣旋生成時間統計

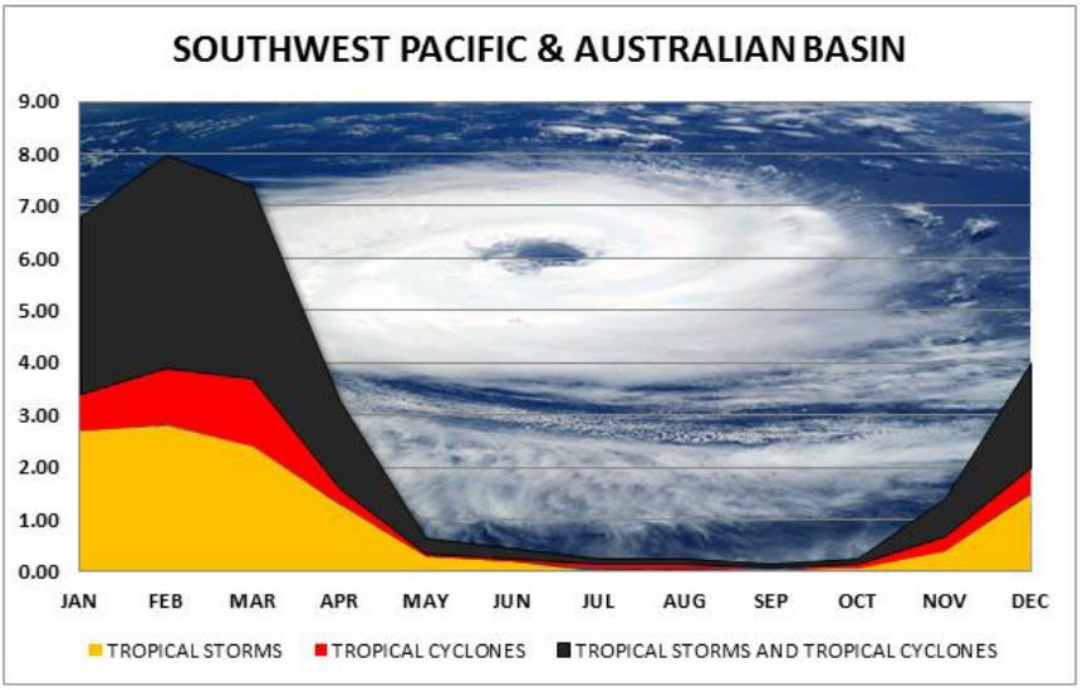


圖 22：南半球熱帶氣旋生成時間統計

為掌握世界各區域之熱帶氣旋情況，世界氣象組織共設置了六個熱帶氣旋區域專業氣象中心（RSMC)，分別位於邁阿密、東京、新德里、留尼旺島、楠迪（斐濟）及檀香山，連同六個負有區域責任的熱帶氣旋預警中心(TCWC)，分別位於珀斯、達爾文、布里斯班、莫爾茲比港、惠靈頓及雅加達，提供有關所有熱帶氣旋、颶風、颱風的最新一級基本氣象訊息的諮詢和公告（分布及負責區域如圖 23）。

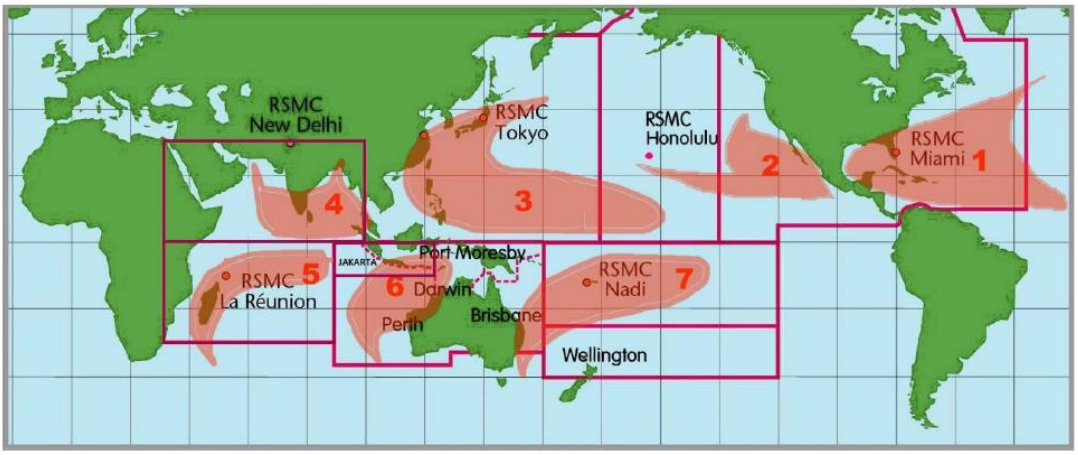


圖 23：各熱帶氣旋預警中心負責區域

而西北太平洋各月份之熱帶氣旋行進路徑統計如圖 24:

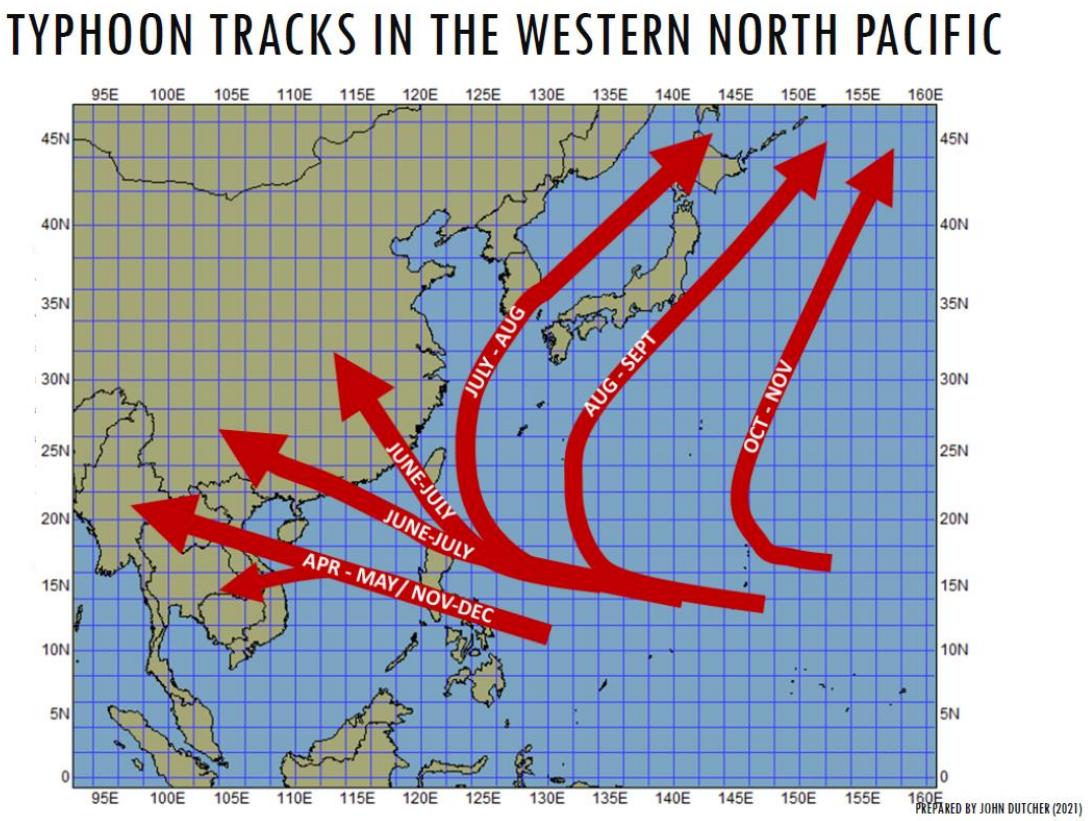


圖 24：西北太平洋各月份之熱帶氣旋行進路徑統計

再就氣候統計資料顯示（如圖 25、圖 26），臺灣地區屬於熱帶氣旋侵襲之熱區，侵襲機率高，侵襲時間約 1 至 2 日，因此臺灣地區（即臺北飛航情報區所在）之熱帶氣旋預警報作業為維護飛航安全之重點業務項目。

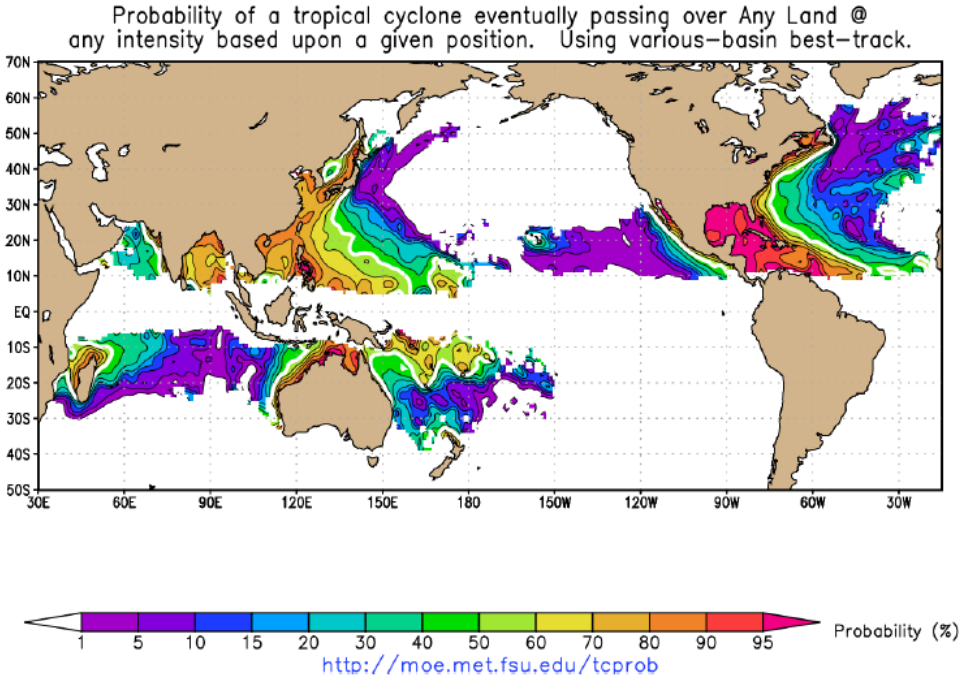


圖 25：熱帶氣旋侵襲機率

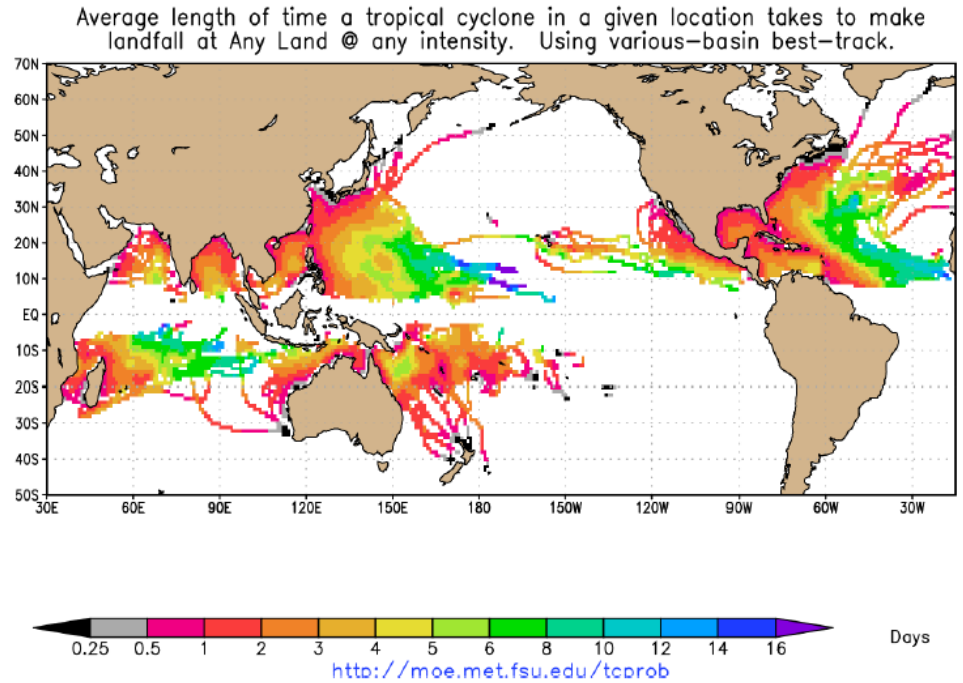


圖 26：熱帶氣旋侵襲時間長度

九、 以系統方法調查天氣事件（A Systematic Approach to the Investigation of Weather Occurrences）

(一) 天氣事故調查 3 階段

與天氣有關的事故調查包括資料收集、資料分析及報告結果三個階段(如圖 27)。

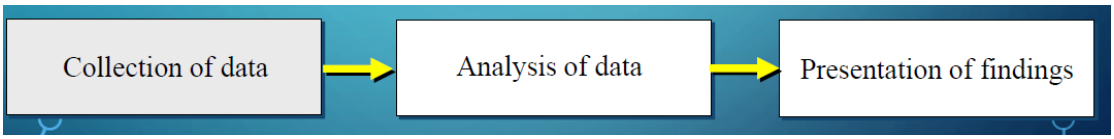


圖 27：天氣事故調查 3 階段

而事件調查應優先考慮以下幾點：

1. 什麼元素可能對飛機運行很重要？例如，霧、雲、風、風暴等，以及其對於飛機的影響。
2. 飛行員/管制員等可以獲得哪些信息以及如何獲得?他/她可以解釋信息並應用它嗎？

為使調查工作順利進行，調查人員應該優先具備以下能力:

1. 透過觀看資料瞭解完整的天氣情況，並充分掌握天氣成因和演變。
2. 預測未來天氣的發生及可能影響飛行的危險。
3. 能夠做出關於天氣的明確分析結果。
4. 為分析結果訂定建議事項。

(二) 資料收集

在蒐集資料過程中，應先收集優先蒐集易變質的資料後，其次再蒐集持續中的程序，蒐集資料內則應包含事件詳情、氣象、技術及人為因素。而事件詳情應該包含發生日期（UTC 和 LMT）、發生時間（UTC 和 LMT）、發生地點（一般位置、網格參考位置及海拔和地形）、出發點、巡航高度或飛行高度、目的地和中間站點（帶有 ETA 和 ETD）以及雷達軌跡。氣象資料部分則需要雷達、衛星、地形、飛機報告、探空資料、氣象數值模式資料、高空分析及預報資料、閃電資料及地面資料（如 METAR/SPECI 及 TAF 等等）。

因為調查過程屬於持續進行之工作，因此調查人員需要訂定天氣資料檢查表（Weather Package），以便確認資料蒐集是否完備（如圖 28）

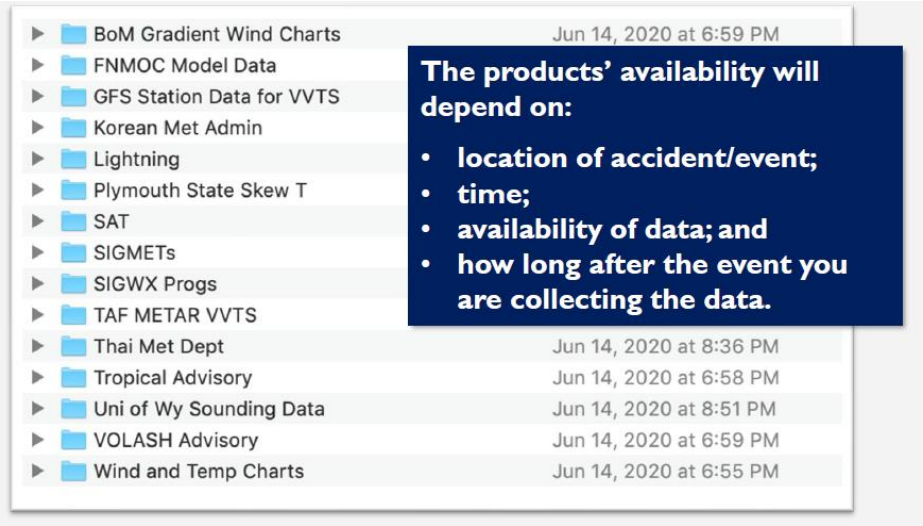


圖 28：天氣資料調查表

同樣的機組人員在執行飛行任務前，天氣簡報內容亦應包含與 Weather Package 相同之天氣資訊。此部分已於 ICAO Annex 3 之 9.3 「Flight documentation」有明確規定。

而在技術資料部分應該包含氣象裝備維修及測試資料，與各類天氣工具相關資訊。而在人員資料部分則應該包含人員個人資訊、工作場所（任務和環境）可能造成錯誤或違規的條件、公司管理決策和組織流程等。

(三) 資料分析

本階段應仔細考慮從相關時間內可用的預測和觀察資料中，看出可能存在的危險現象。以氣象資料而言，應嘗試由 4 維空間（加入時間）及不同空間及時間尺度方式了解各資料所代表意義，如 500hPa、700hPa 及 850hPa 於不同緯度所代表之意義即不相同。另外也需要考慮現有預報資料及技術之弱點。而在事件資料分析部分，則著重在壓力高度/高度的計算、當地天氣可能受周圍地形之影響、結合發生日期和時間識別當地風場情況（如事件發生時為海風或陸風）以及由雷達軌跡資料了解飛機組員可能遇到的情況。再以檢查表的方式將前述各項資料以固定的邏輯連貫，確保資料分析結果穩定。

技術資料分析部分，則著重於設備維修、測試及運作情況，如設備準確度以及是否提供明顯的錯誤資訊（如-TSRA 錯誤解譯為 light thunderstorm with rain）部分；人員資料分析則著重在人員本身、工作環境以及公司組及與決策內容。

(四) 報告結果

事件調查結果應提交給管理層（可能也是委員會），並在調查報告中提供調查結果摘要。而合理的調查技術將有助於進行全面的分析，並有助於對調查結果和可能的因果因素進行簡單的總結。

對於事件的系統性分析應提供事件因素發生原因的充分說明。而對於事件之天氣相關數據的準確性、顯示、規範和傳播相關之分析，應有助於識別人為和技術相關事件發生因素。

就目前的事件調查仍有許多限制存在，如資料可用性不足、資料量不足以及其他技術部分的限制，故調查員不得不採取創新的方式進行資料分析，或透過與其他專業領域之人員合作進行調查。

十、 支持決策的主動預測系統（Proactive Forecasting Systems for Supporting Decision Making）

灰碼系統(Code Grey System)

影響航空公司正常營運的主要原因有天氣因素（如風力風向、濃霧、低雲及雷暴等）、設備因素（航管雷達、系統停機）、跑道因素（跑道維護等）、空域容量等。其中天氣預報在商業航空扮演重要的角色，影響航空公司燃油規劃、航路規劃、亂流避讓、機場容量計劃、維護作業、飛航服務計劃、乘客計劃、組員調派計劃，所以需要精準的天氣預報，有賴航空氣象服務提供完整資訊，包含顯著天氣預測圖（SIGWX Prog）、機場天氣預報（TAF）、機場例行天氣報告（METAR）、機場特別天氣報告（SPECI）、飛機報告（AIREP）、顯著危害天氣（SIGMET）、低空危害天氣資訊（AIRMET）、機場警報（Aerodrome Warning）、低空風切警報（LLWS Warning）。

依據近來大部分統計顯示，美國對儀器天氣（IFR）的預測準確率可達 64%，但是同時也說明不準確率有 36%，天氣變化有時會影響航班時刻，除造成乘客不便和公司負面形象之外，這對航空營運商和機場管理部門來說都可能造成不小經濟上的損失。

航空公司簽派員必須考慮到由於阻礙天氣因素而導致延誤的可能性，並決定是否應將額外的燃料裝載到飛機上。必須在飛機起飛前 1 到 2 小時做出關於航班起飛後 2 小時或更長時間的未來天氣狀況的決定。因此，這些決定需要準確和及時的預報，而這些預報完全依賴氣象部門所提供機場天氣預報(TAF)。TAF 預報之天氣有其規定，必須至少有 30%發生機率或更多的顯著現象（即雷暴、霧），其中使用 TEMPO 和 BECMG 還有其他限制。最終結果是 TAF 通常是保守的，即使預報員可能認為這種現象可能發生在預測期內。預報員必須注意他們的 TAF 在航空公司推動營運決策方面的潛在影響。

為了降低現有天氣資訊（依照國際民航組織規定），仍有不足情況之風險，有了「灰碼系統概念（Code Grey System Concept）」，也就是有可能（低於 30%）影響營運商和機場的重大天氣現象操作，應該向建立一套通報系統提供相關天氣資訊。在澳大利亞，氣象局預報員在內部使用一種稱為“灰色代碼”的系統來處理概率 10-20%的重大天氣現象。這在內部向預報員發出信號，要求他們持續監測情況，看看它們是否會進一步發展，從而對 TAF 進行修正。航空運營商或機場可以採用他的“灰色代碼”系統，他們可以比平時提前幾個小時開始製定營運計劃，同時不斷監測情況並更新他們的計劃。灰碼系統發展仰賴天氣和氣候數據的詳細分析，並訪談航空公司機組員、簽派員進行認知及任務分析。建構灰碼系統，效益是簽派員可以提高他們的預測和營運績效，改善駕駛艙的決策，尤其是在國際航班上機組人員。

改善簽派員與飛行中機組人員持續監測天氣狀況並做出改航至備降機場等的決定。除了增強決策和安全性之外，該計劃還可以顯著節省燃料成本。建構灰碼系統可以利用不同工具，如發展氣候統計、強化機組了解影響天氣動力條件、解說數值天氣預報、訓練其使用其他工具，如斜溫圖、穩定度指標等。但要注意該系統目的在於容易出現霧、其他低能見度現象和顯著危害天氣（即雷暴、結冰、亂流）的地區，提供機組人員和航空公司額外天氣資訊，它並不意味著要取代傳統的機場預報(TAF)。

決策支持系統（Decision Support System）

為了改善安全及作業，支援決策系統是未來航空氣象服務之重點業務，要善用圖表式的產品(如圖 29、圖 30)，提高產品認知使用效率。並建立機場及航路顯著天氣（雷暴或積雨雲）預測工具(如圖 31、圖 32)，以利航空公司及機場營運決策參考。

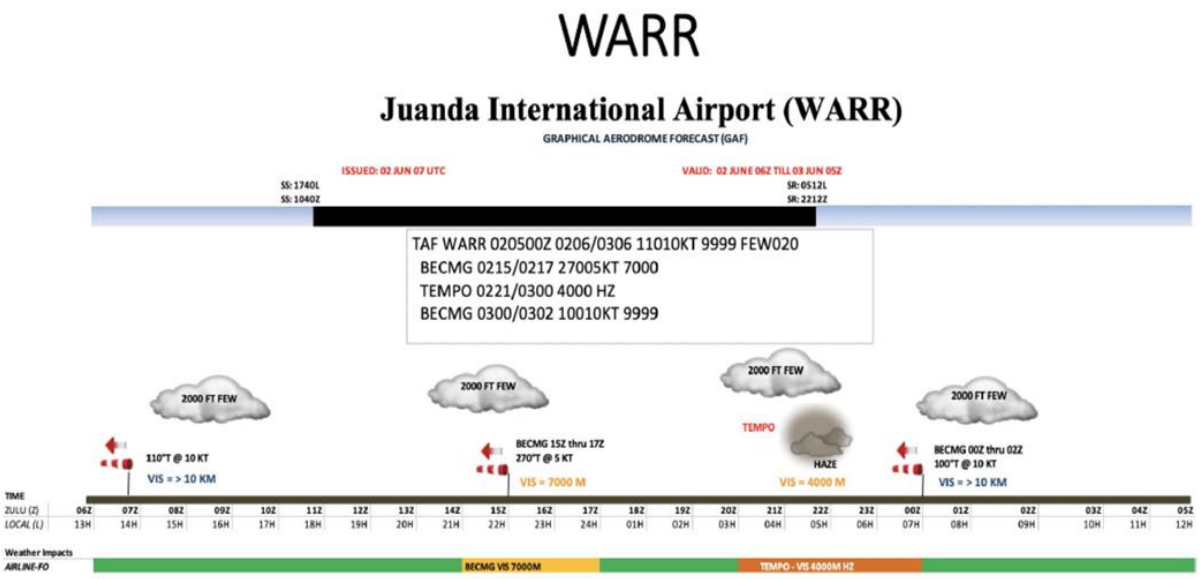


圖 29：印尼朱安達國際機場 TAF 之圖形化產品

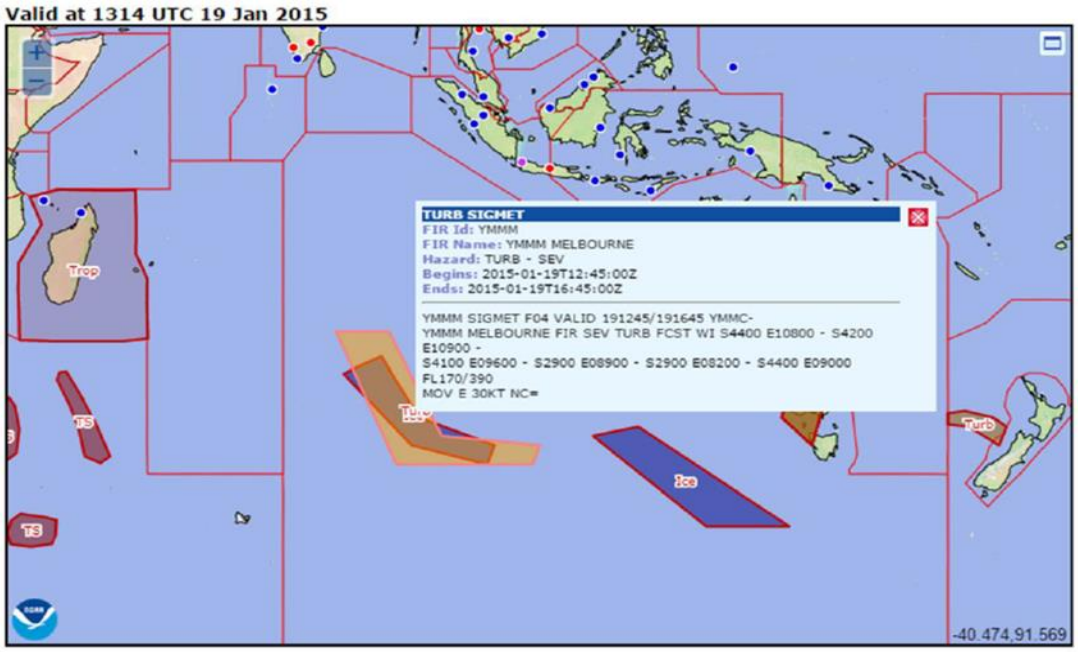


圖 30：NOAA SIGMET 報文及圖形化比較

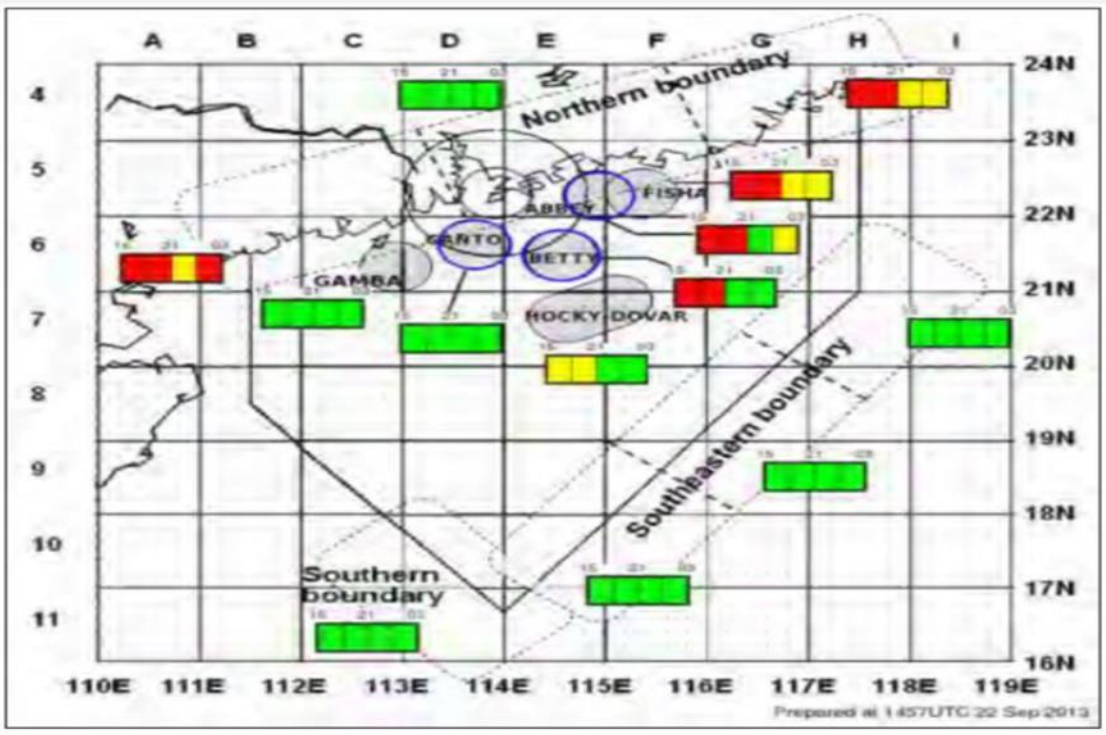


圖 31：香港機場附近重要飛機報告點未來 12 小時顯著天氣預測警示資訊

Figure 19: 9-hr performance-based weather forecast for the aerodrome *(HKIA)*

Level	Head wind	Cross wind	Visibility	Ceiling
1	=< 20 kt	< 30 kt	> 1000 m	> 400 ft
2	21 - 40 kt	30 - 35 kt	600 – 1000 m	200 – 400 ft
3	> 40 kt	> 35 kt	< 600 m	< 200 ft
-	< -5 kt	-	-	obscured sky

圖 32：香港機場未來 9 小時風、能見度及雲幂預測資訊

決策支持系統提供在天氣變化時調整計劃。需要客製化，聚焦在資訊使用者需求。氣象事件不是單純歸類為氣象問題，我們應更進一步提供支持決策，並管理天氣在安全及作業上的影響，這就是天氣風險管理的意義。不僅止於行為問題，而是單位文化議題。安全察覺及訓練(製定合宜飛行計劃，飛行中依天氣資訊調整，避開天氣風險)是最好的實踐，可以識別並解決法規和程序/政策中的重大漏洞。決策支持必須改善將天氣數據上傳到駕駛艙的功能，也同時必須改進飛機將天氣數據下傳給相關飛航單位，可使航空氣象作業即時參考航機所遭遇之天氣。

十一、 天氣風險管理之改變及改善（Change and Improvement of Weather Risk Management System）

飛行中失控、可控飛行下撞地及衝偏出跑道（Lost of Control-Inflight, Control Flight into Terrain 及 Running Excursions），前述三個失事面向亦為歷年來全球失事之前 3 大主要型態。據 2016-2020 天氣統計資料，所有事故中 37%受天氣因素影響。2014 年至 2018 年間發生的致命事件為 53%，55%的衝出跑道事件與天氣有關。71%落地過早事件與天氣有關，47%飛行中失控事件與天氣有關，100%的可控飛行下撞地事件與天氣有關。天氣對於安全、效率及航空作業容量有主要的影響，飛安意外及飛安事件仍會持續受不良天氣影響，使乘客面臨一些不便，如延遲起降、取消班機、轉降及甚或受傷意外。

FOC（Flight Operations Control），在航空公司 FOC 歸屬運行控制單位，飛行簽派人員、地面服務、機務維修、飛行、乘務排班、乘客餐飲準備等等，一架飛機起飛、落地需要的所有決策作業均匯集於此。他們 24 小時不休地準備航前資料，檢視航班動態，處理緊急突發狀況，保障航班的可安全、正常運行。其中影響航班時刻正常運作的 2 個主要原因就是航機設備維護及天氣因素。由於現在仍有飛安意外，顯現我們做的還不足，仍然缺乏對天氣事件的重視，以長期營運角度來看，天氣因素已是營運的成本，必須與時俱進來管理天氣相關作業，尤其在推進下一代飛航管理系統。

天氣風險管理系統（Weather Risk Management Systems，WRMS），是一套完整方法去管理天氣的衝擊，由一系列天氣風險控制，管理天氣危害如雷暴、亂流、低能見度、低空風切等對安全及作業的影響。WRMS 是管理系統的一部分。在日益擁擠的天空中，準確及時的天氣觀測、預報和警告對於空中交通的安全和效率至關重要。如決策支援系統、對駕駛員、簽派員及管制員較好的氣象訓練，必須使用基於風險的管理方法，從單一隔絕系統轉變為“系統對系統”之天氣風險管理系統，是整合式天氣資訊決策系統。其效益在於，基於風險流程去設計，可改善氣象產品。能夠預測延誤可以幫助航空公司從戰略上避免經濟損失。加強與利益相關者的合作和溝通，改善公司安全績效，改善燃油作業，提高作業可靠性/可用性，改進的產業安全認證。WRMS 必須適合組織的規模、性質和風險，為整體安全業務管理以及日常營運規劃的一部分，需要高層管理承諾，系統控制以確保及時識別危害。

管理承諾及支持，向管理層和高級員工介紹飛機事故中的組織/系統因素。通過面對面的討論，向管理層提供有關減少天氣安全事件中的系統/組織因子。至於 WRMS 相關訓練，項目有安全管理者之天氣風險管理系統訓練、應用氣象資訊訓練、飛機事件氣象調查、有關氣象之飛行計畫簽派訓練、查核及審視、文件控制及管理、資料庫訓練等。與 SMS 一樣， WRMS 具有可擴展性和靈活性，可以根據您的組織進行定制—如國際長途、包機、貨運飛機及飛航服務性質等，任何組織（無論大小）都可以實施 WRMS 以更好地主動管理天氣對其運營的影響。

改變管理的階段，第 1 階段：面對問題，第 2 階段：改變作業缺失解決問題，第 3 階段：達到安全目標並持續改善。在心態上，可以打破傳統思維，放眼未來；動機上，處理對損失的反應並創造改善的動機；行為上，改變行為和發展能力。

支持決策系統，包括“天氣決策”Decision Support Systems (DSS)，決策輔助，例如 清單（checklist）、流程圖（flowcharts），不同介面的合作如管制員、氣象辦公室及機場營運部門。專業發展和強化教育（知識和技能），明確的天氣政策和程序，必須超越 ICAO Annex3 既有框架，解決現在氣象產品資訊之不足。有關 WRMS 訓練模式，現行訓

練重視氣象理論教學，偏重單一課程的測驗，未來應重視實用天氣技能和情境演練學習，可能發生之情境演練訓練、飛行員可應用於他們面臨的情況的天氣專業知識、識別地面和飛行中天氣危害、改進飛機氣象雷達應用訓練等。

十二、 訓練實作

此部分以本次課程所學有關天氣風險管理流程 5 個步驟(建立事件起因-危害識別-進行風險分析-風險評估-風險控制改善措施)來進行風險評估及風險控制。

以桃園機場為例，利用危害識別及風險評估控制表(HIRAC，如表一、表二)來評估低空風切及低能見度對於航機的風險指數為何，進而判斷是否需要進一步的控制措施以降低風險。

表一：危害識別及風險評估控制表(低空風切)

編號	危害項目	影響程度	可能性	現有控制措施	現有風險指數	新增控制措施	殘餘風險指數
1	低空風切（風切大於15KTS）	4，屬於重大	C，11-50%，考量低空風切警報系統能有效降低航機遇到低空風切的可能性。	1.在跑道中間設置風向風速計 2.機場例行天氣報告(METAR)及機場特別天氣報告(SPECI)之供應 3.當機場發生顯著天氣時，ATIS系統能即時更新氣象資訊 4.機師在風切環境下對飛機之操作限制 5.機師重飛之執行能力 6.機場及飛航服務之資源規劃。 7.低空風切警報系統	**4C，屬於中度危險**	1.機場更多個位置安裝風向風速計 2.飛機換跑道程序 3.五邊降落時避免航機距離太過接近	**4D，屬於中度危險**

表二：危害識別及風險評估控制表(低能見度)

編號	危害項目	影響程度	可能性	現有控制措施	現有風險指數	新增控制措施	殘餘風險指數
1	低能見度（能見度低於 1000 公尺），但 RVR 大於 300 公尺	3，屬於中度	D，1-10%，考量第 2 類儀器降落系統有助於機師不受低能見度影響而順利降落	1.在跑道中間設置能見度儀。 2. 機場例行天氣報告(METAR)及機場特別天氣報告(SPECI)之供應。 3.當機場發生顯著天氣時，ATIS 系統能即時更新氣象資訊。 4.機師在低能見度環境下對飛機之操作限制 5.機師重飛之執行能力 6.機場及飛航服務之資源規劃 7.第 2 類儀器降落系統	**3D，屬於低度危險**	1.機場更多個位置安裝能見度儀 2.塔臺換跑道程序 3.五邊降落時避免航機距離太過接近	**3D，屬於低度危險**

利用危害識別及風險評估控制表來評估桃園機場的低空風切及低能見度對於航機的風險指數為何，有助於判斷是否需要進一步的控制措施以降低風險。由於桃園機場已裝設低空風切警報系統，有效避免機師在風切環境下落地，大幅降低低空風切造成危害的可能性，風險指數在可接受範圍，不需要進一步的控制措施。另由於桃園機場已裝設第 2 類儀

器降落系統，有助於機師在低能見度環境下落地，大幅降低低能見度造成危害的可能性，風險指數在可接受範圍，不需要進一步的控制措施。

透過天氣風險管理流程可以分別得到低空風切的風險值為 4D，而低能見度的風險值為 3D，因此當氣象觀測人員當同時遇到低空風切及低能見度時，應優先發布低空風切警報並通報相關單位，之後再處理低能見度發生時應完成之作業，如此就能提供更安全之氣象服務。

肆、心得與建議

一、 善用危害識別及風險評估控制表(HIRAC)來評估不同天氣對於作業風險等級，進而判斷、研析，採取適當措施以降低作業風險

建構安全的天氣服務網是最重要的議題，正確性與即時性對於天氣資訊來說都非常重要，天氣服務的難題就是要同時兼顧正確性與即時性，如何解決就需要**透過安全管理系統來量化每一項風險的風險指數，協助氣象作業人員在關鍵時刻作出適當的行動**。利用HIRAC，對於各項天氣危害做風險評估，讓氣象作業人員熟悉各項天氣對於航機的風險指數為何，有助於氣象作業人員當遇到惡劣天氣時能夠決定作業的優先順序，進而提供更安全之氣象服務。

二、 導入系統方法調查天氣事件概念，建構完整飛航安全所需之航空氣象資訊

經由本課程了解到天氣有關的事故調查流程及方式，其中 Weather Package 的訂定有助於調查人員瞭解資料蒐集情況及資料分析邏輯。臺北飛航情報區之飛機事故調查辦理單位為國家運輸安全調查委員會（下稱運安會），為提升總臺與運安會對於事件調查之共識，建議**可透過雙方研討交流，瞭解氣象資料之應用及提供程序，除加速事件資料蒐集效率與品質外，亦有助於調查之進行。**

三、 不定期與飛航用戶討論，提供符合其作業所需資訊或協助其建立有利於作業運用之航空氣象資訊系統

因應不同飛航用戶所需航空氣象資訊，建立多元化氣象資訊傳報管道或系統(即灰碼系統)，可增強航空公司、機場營運部門等天氣應變作業能力，比如說不同航空公司不同機型側風限制不同，需要更符合其需求的風向風速預報資訊，以上可與使用者進行需求討論並了解其實際作業影響等，**建議總臺持續不定期與使用者研商，了解其需求，進行相應調整及強化。**

四、 持續投入研發飛航用戶所需之航空氣象資訊支援決策系統（Support Decision System）

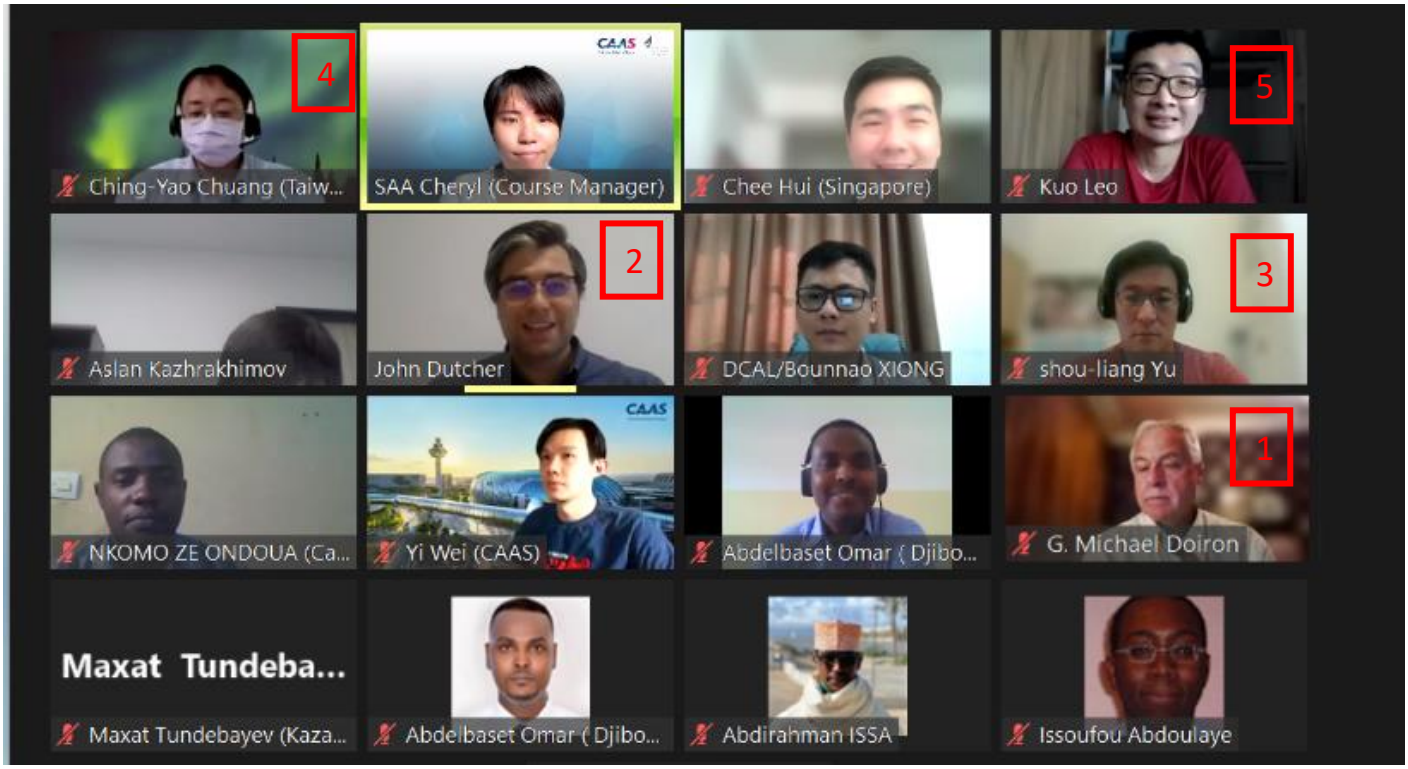
天氣支援決策系統是未來航空氣象服務之重點業務，要善用圖表式的產品，在與飛航用戶的交流會議，駕駛員及簽派員亦反映圖形化資料，有利於其掌握及運用資訊，本總臺現行於航空氣象服務網提供 TAF 圖形化預報資料，利於航空公司簽派作業使用。另本總臺自 110 至 113 年刻正執行**航空氣象現代化更新及汰換計畫，將藉由美國大氣科學研究中心(NCAR)協助，透過系統升級引進最新預報科技，產出高解析度預報輔助資料及機場未來 7 小時即時雷雨預報資訊，屆時將可提供航空公司營運決策有利參考。**

伍、附錄

一、 視訊上課截圖

二、 Weather Risk Management Process 簡報

視訊上課截圖



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2. Mr. JOHN DUCHER

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4. 臺北航空氣象中心 莊清堯主任氣象員
5. 臺北航空氣象中心 郭力瑋預報員

Weather Risk Management Process

Aviation Weather Risk Management (AWRM)

Singapore Aviation Academy

20 – 24 Sept 2021

JOHN DUTCHER &
MIKE DOIRON

SINGAPORE AVIATION ACADEMY

PRESENTATION OUTLINE:

1) Introduction
2) Weather Risk Management Process
3) Weather Risk Control
4) Exercises Throughout

01

INTRODUCTION

Prepared by John W. Dutcher (2021)

ROLE OF ITCZ IN LOC-I

Safety Management of Flight Operations in Adverse Convective Weather and the Inter-Tropical Convergence Zone

Description:

….

- Inclement weather and atmospheric disturbances are potential contributory factors to loss of control in flight (LOC-I). Hence the need for effective safety management adapted to the specific risks related to flight operations in the ITCZ.

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EASA, 2015 – SIB 2015-13

Prepared by John W. Dutcher (2021)

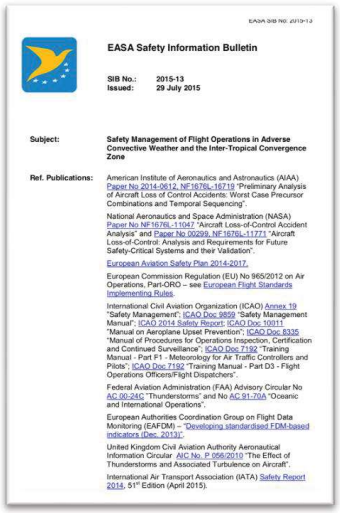
EASA SIB – 2015-13

Safety Management of Flight Operations in Adverse Convective Weather and the Inter-Tropical Convergence Zone

Recommendation(s):

.....

- Safety management principles should apply to all aspects of flight operations in adverse convective weather and the ITCZ with a view to implementing risk mitigation strategies and proactively taking preventive actions.



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EASA, 2015 – SIB 2015-13

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WEATHER RISK MANAGEMENT SYSTEM (WRMS)

- 'Holistic' approach to managing the impact of weather
  - 'Big Picture' approach
- One master WRMS integrated within the overall SMS
  - WRMS documented as a SMS Work Instruction (Level 2-3 document)
  - Perhaps a series of SMS Work Instructions on key threats: LOC-I; Fatigue; CFIT, etc.
  - WRMS as an example of SMS Continuous Improvement and expanded Safety Risk Management
- Comprised of a series of Weather Risk Control Systems (Wx-RCSs) designed to manage the impact of weather hazards on safety and operations.
  - Wx-RCS for Turbulence
  - Wx-RCS for Thunderstorms
  - Wx-RCS for Reduced Visibility,
  - Wx-RCS for Low Level Wind Shear (LLWS)

WRMS per the ICAO 9859 Framework

SMS Framework	WRMS Framework
Safety policy & objectives ○ Management commitment and responsibility ○ Safety policy ○ Safety accountabilities ○ Appointment of key staff members ○ Safety response planning ○ SMS documentation	**WRMS policy & objectives** ✓ Management commitment ✓ WRMS accountabilities and responsibilities ✓ Weather Risk Management policy ✓ WRMS objectives ✓ WRMS processes and procedures ✓ WRMS documentation
Safety risk management ○ Hazard identification ○ Risk assessment and mitigation	**Weather Risk Management (WRM)** ✓ Identification of weather-related hazards ✓ Assessment of weather-related risks – *e.g., airports, routes, airline, airspace, etc.* ✓ Weather Risk Control Systems/risk mitigation ✓ Implementation of Risk Treatment Plans
Safety assurance ○ Safety performance monitoring and measurement ○ Management of change ○ Continuous improvement	**WRMS assurance** ✓ WRMS performance monitoring & measurement ✓ Processes for managing change (to the operational/organisation environment and/or to the WRMS itself) ✓ Weather Investigation ✓ Auditing ✓ Management review ✓ Continuous improvement of the WRMS
Safety promotion ○ Training ○ Safety communication	**WRMS promotion** ✓ Training programs ✓ WRMS training records ✓ WRMS communications

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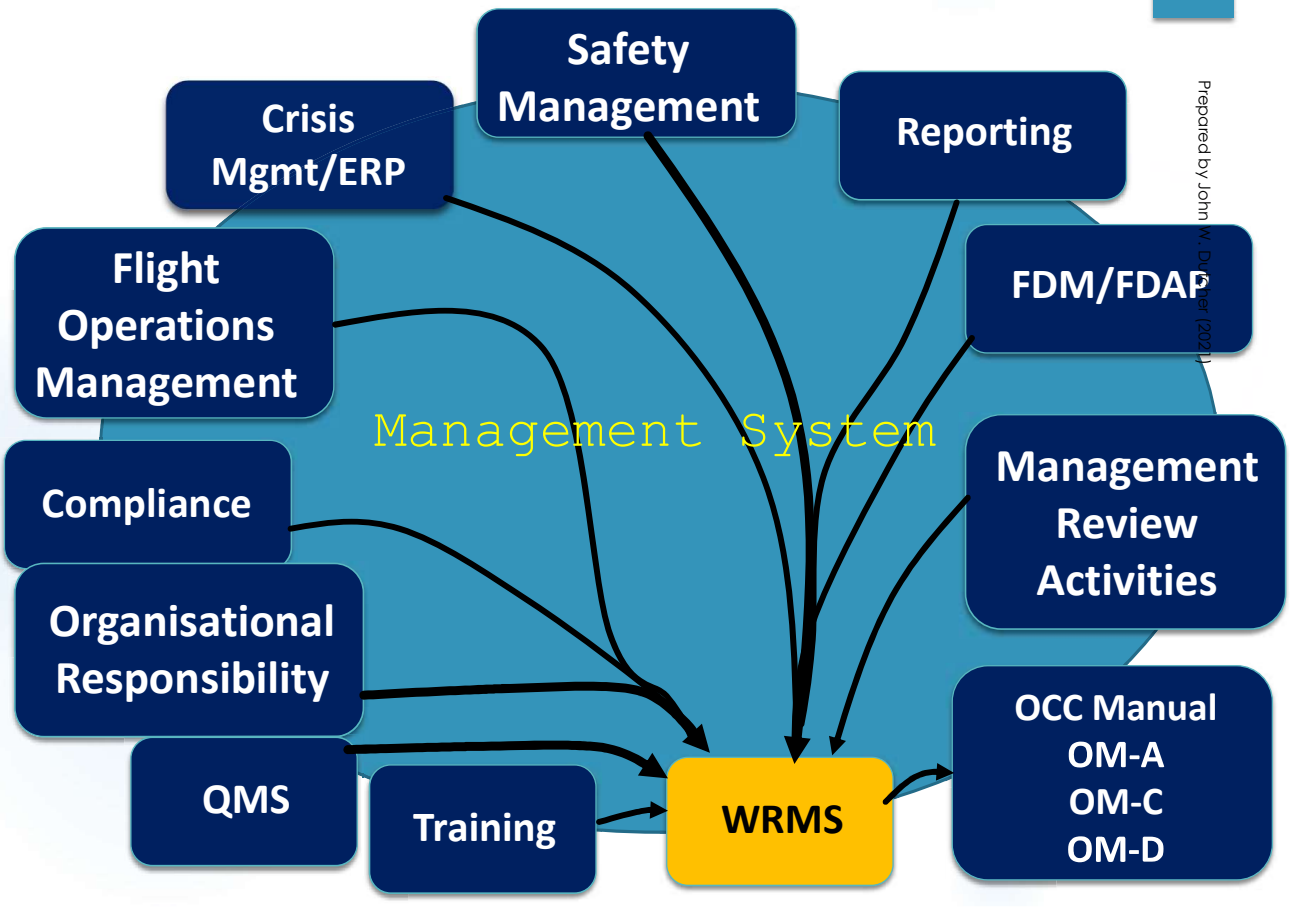
(Dutcher, 2017)

WRMS as part of Management System

[Airline Example]



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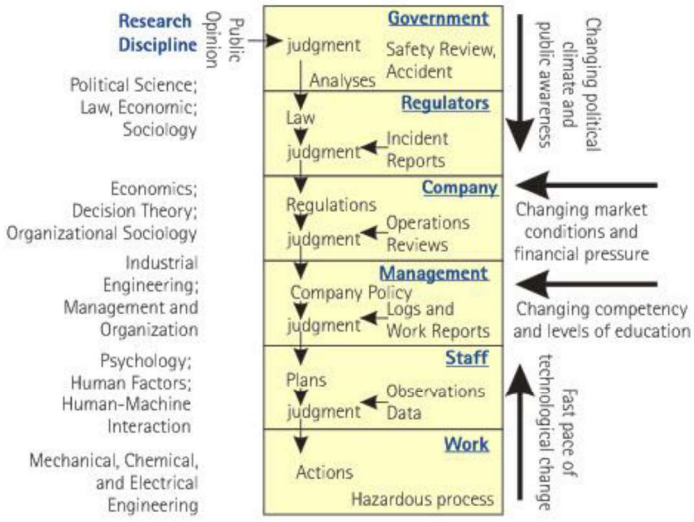
RELATIONSHIPS

- Risk management is a systems-based approach
- The system concept can be understood and applied within all levels of the organisation; and system (regulators)



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02

WEATHER RISK MANAGEMENT PROCESS

MANAGING OUR INTERACTIONS WITH WEATHER

Prepared by John W. Dutcher (2021)

WHAT IS WEATHER RISK MANAGEMENT?

- The **combination** of **Risk Assessment** & **Risk Control**, with mechanisms for Periodic Review and Risk Communication…

- ***Periodic Review***
  - This lets us use new info (e.g. market and route surveillance, deviations, process experience, weather-related events, etc.) to increase knowledge about weather-related hazards, and to improve the **Risk Assessment.**

- ***Risk Communication***
  - Necessary and critical - helps promote a culture of weather risk awareness.

Prepared by John W. Dutcher (2021)

RISK CONCEPTS, DEFINITIONS & GENERAL CONSIDERATIONS

Prepared by John W. Dutcher (2021)

HAZARD VS. RISK

- **Hazard =** Condition or situation that may cause harm.

- **Risk =** The chance of injury or loss

STRONG WINDS

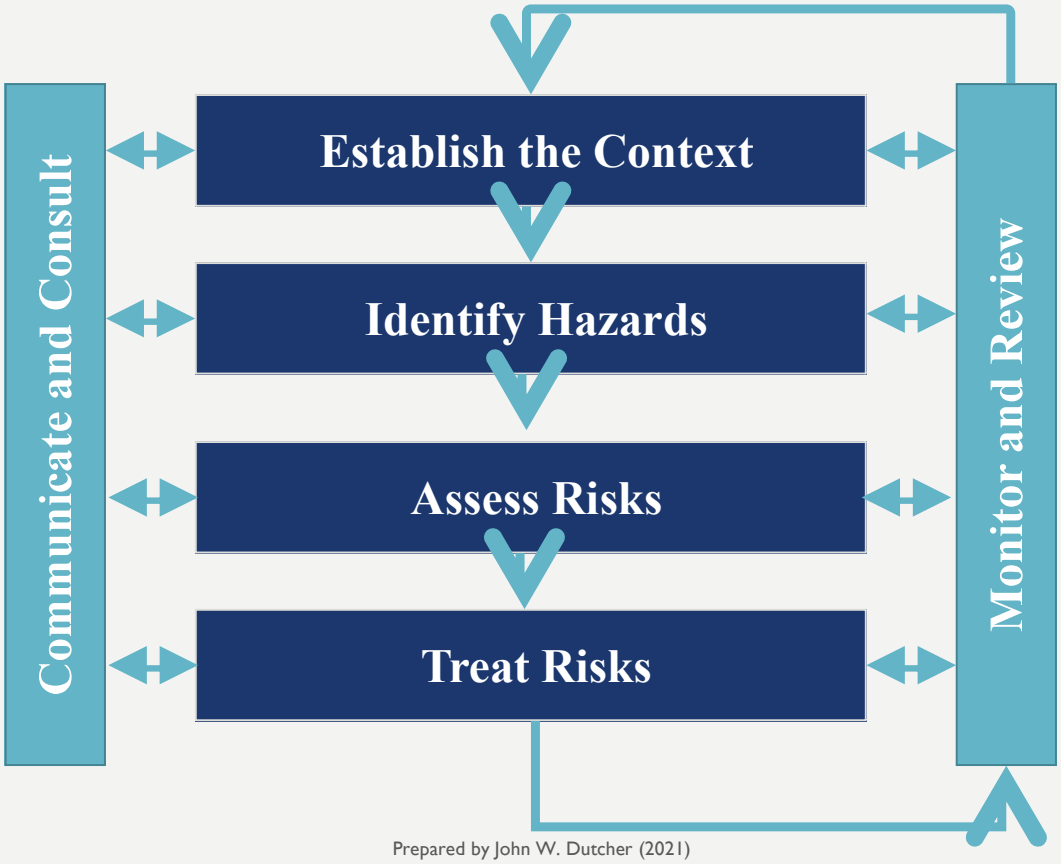
TWO DEFINITIONS

- **Hazard** – Condition or object **with the potential** of causing injuries to personnel, damage to equipment or structures, loss of material, or reduction of ability to perform a prescribed function
- **Consequence** – Potential outcome(s) of the hazard
  - *A wind of 15 knots blowing directly across the runway is a **hazard***
  - *A pilot may not be able to control the aircraft during takeoff or landing is one of the **consequences** of the hazard*

UNDERSTANDING HAZARDS

- There is a natural tendency to describe hazards as their consequence(s)
  - ***"Runway Contamination"*** *vs.* ***"runway excursion"***
- Stating a hazard as consequence(s) :
  - disguises the nature of the hazard
  - interferes with identifying other important consequences.
- Well-named hazards :
  - allow to infer the sources or mechanisms of the hazard
  - allow to evaluate the loss outcome(s)

WEATHER RISK MANAGEMENT PROCESS



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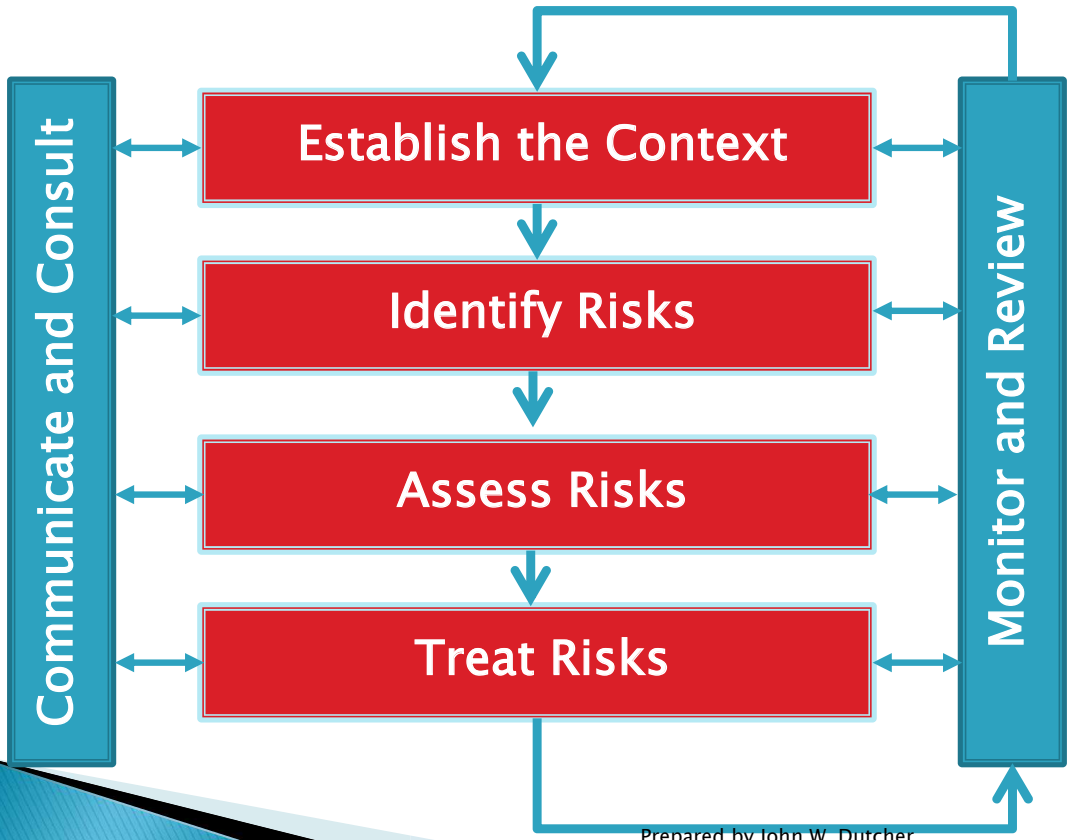
Weather Risk Management Process



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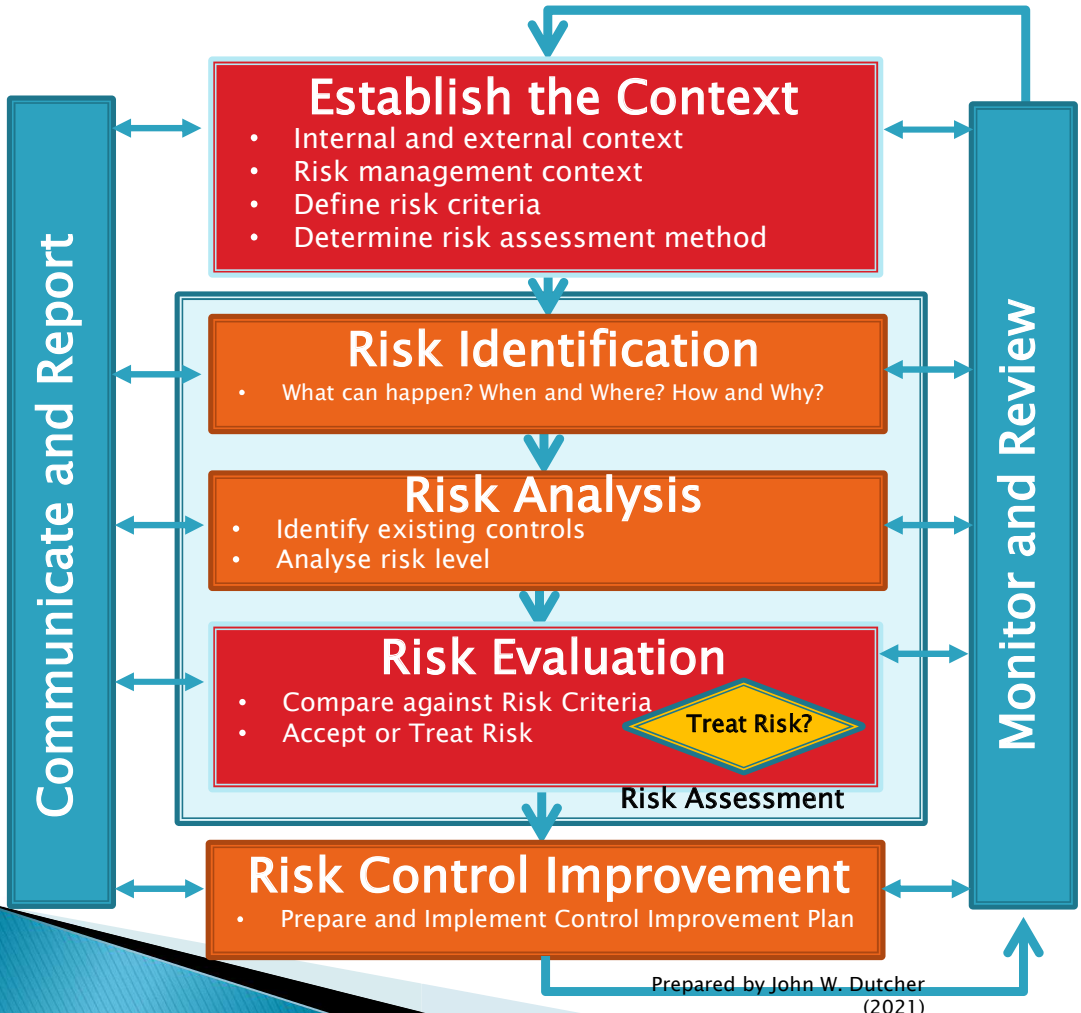
ESTABLISH THE CONTEXT

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)



STEP 1 – ESTABLISHING THE CONTEXT

- Ideally, Establishing the Context will be completed in consultation with relevant stakeholders before any risk assessment forum is convened.
- This phase of the process establishes the external, internal and risk management context in which the rest of the process will take place.
- Criteria against which the risk will be evaluated should be established and the structure of the analysis defined. This portion of the process is scalable to the magnitude of the matter being risk assessed.

ESTABLISH THE CONTEXT

- Locations (terrain, types of weather, etc).
- Enroute? Certain Airports?
- Incident that already occurred? Proactive Risk ID?
- Type of Operations (island hoping, cargo, business, charter, international)
- ATC, MET, FLT OPS, Airport?
- Type(s) of Aircraft
- Aircraft Equipment (Aircraft Radar, CAT II/III, Weather data/images on the flightdeck)
- Type of support (single pilot, crew, dispatch, MET Office, FBO/Commercial Flight Planner, etc).
- Airport Equipment / NavAids
- Met reporting
  - Reliable?
  - Accurate?

STEP 1 - ESTABLISH THE CONTEXT

- Determine the objective of the task
- How does the task integrate with various levels of the organisation?
- Who is impacted by the task?
- What are the measures of success and what risk levels are acceptable?
- Break down the task into component parts

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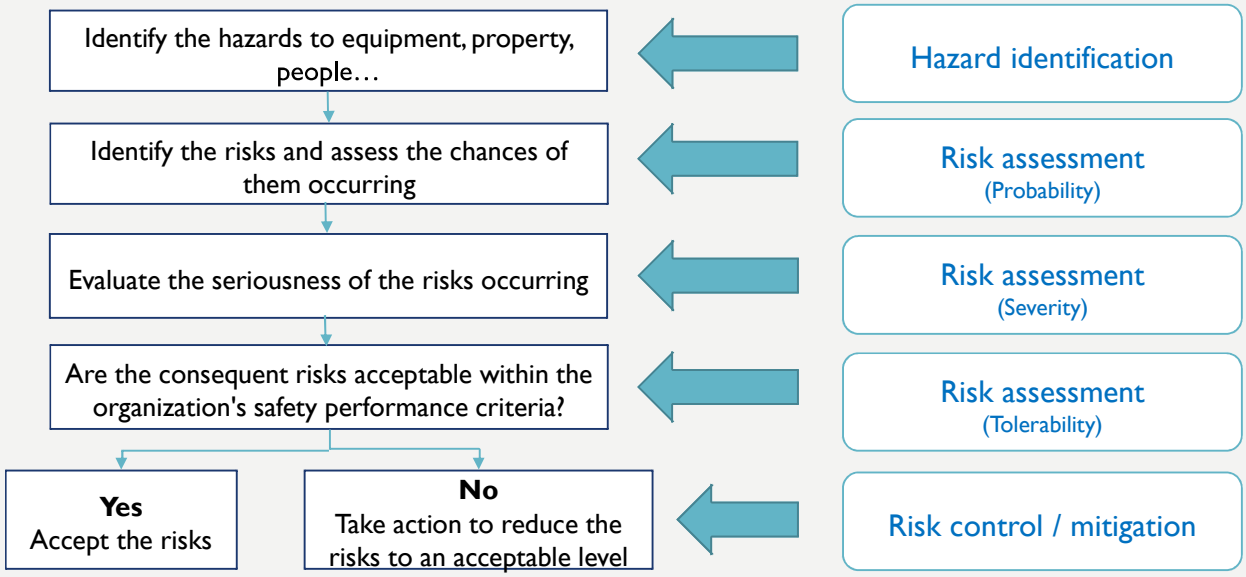
IDENTIFY RISKS (HAZARDS)

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)

RISK ASSESSMENT AT A GLANCE



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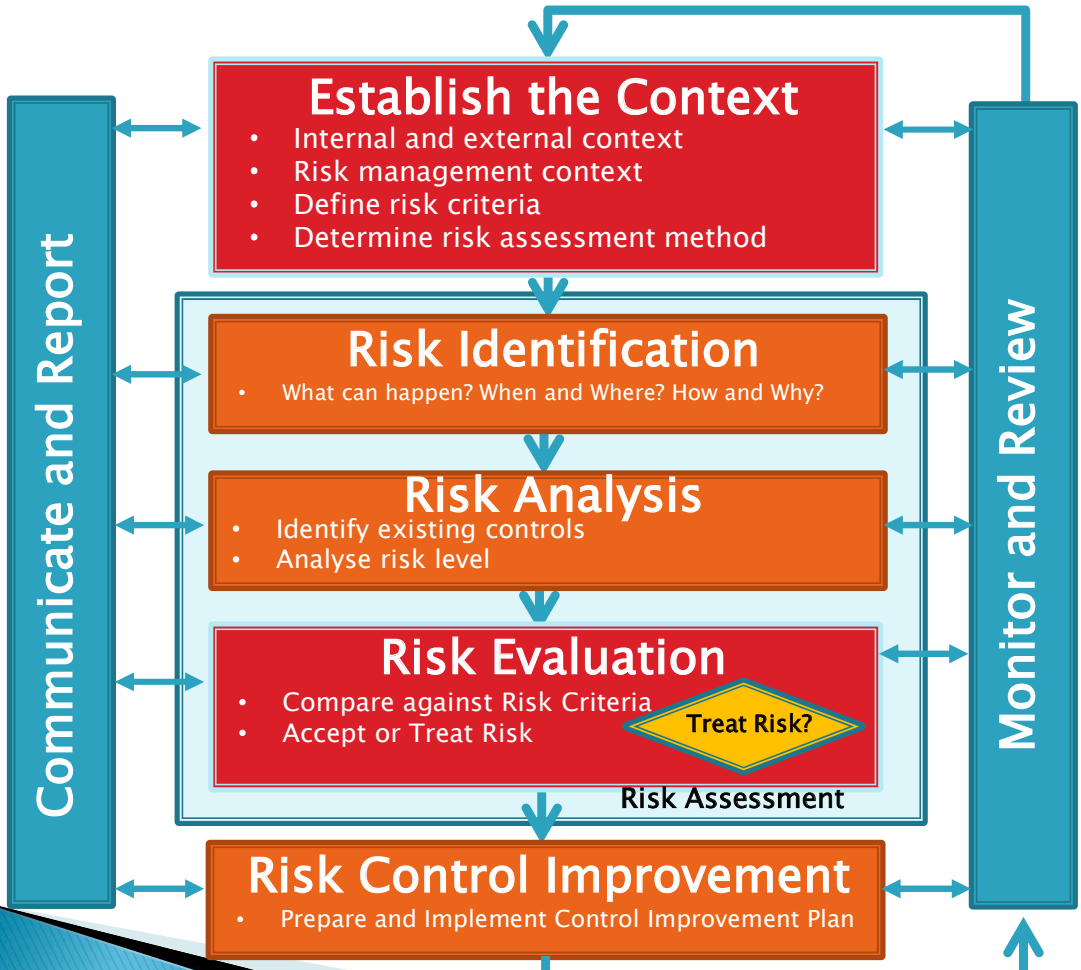

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STEP 2 – IDENTIFYING THE HAZARDS

- Hazard identification is a process where hazards are identified and managed so that safety is not compromised.
- This step seeks to identify hazards that need to be managed.
- A well-structured, systematic process is crucial, as potential hazards not defined at this stage may be excluded from further analysis.

STEP 2 – IDENTIFYING THE HAZARDS

- Effective hazard identification requires expert knowledge of the subject matter, lateral and imaginative thinking and an appropriate structure.
- Using the selected risk assessment method, identify the Hazards (source of harm) that exist and the Risk they may present to the operation.

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SOURCES OF HAZARD IDENTIFICATION

- Reactive
- Proactive
- Predictive
  - **Internal**
    - Company voluntary reporting system
    - Audits and surveys
  - **External**
    - Accident reports
    - State mandatory occurrence system

AVAILABLE RISK IDENTIFICATION TOOLS

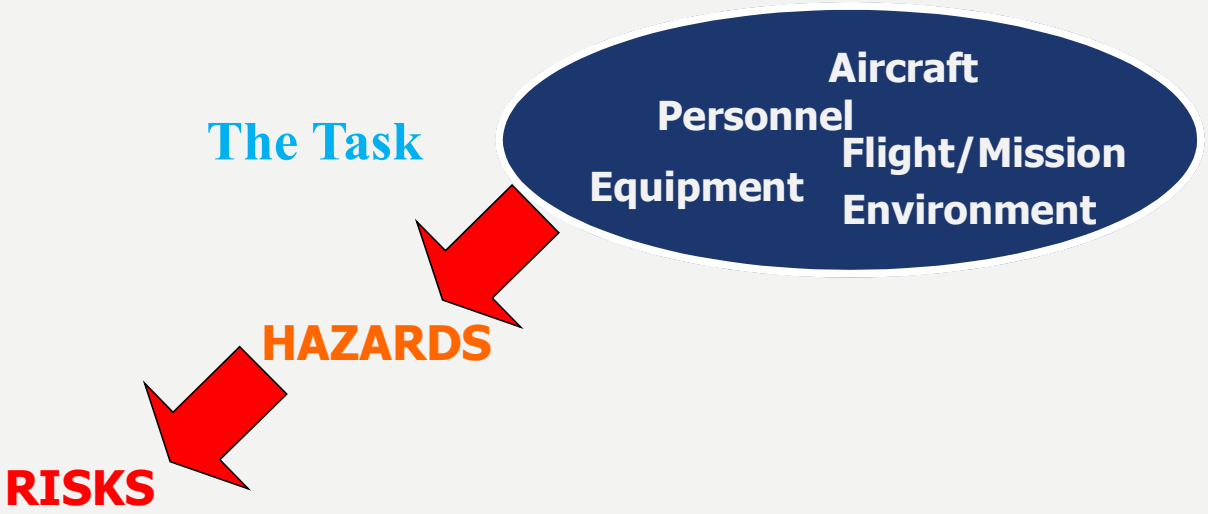
- Brainstorming
- Interview/focus group discussion
- Examination of local or overseas experience
- Expert judgment, peer review
- History/failure analysis
- Audits or physical inspections
- Decision Trees
- Engineering techniques, e.g. hazard and operability (HAZOP) studies
- Operational modeling

STEP 2 – IDENTIFYING THE HAZARDS

- When identifying Hazards and the associated Risk, consider:

1. What can happen? List risks.
2. How can it happen? Consider possible scenarios.
3. Why could it happen? Consider possible causes (Hazards).

HOW DO WE IDENTIFY RISKS?



IDENTIFY RISKS

What can impact the task's objectives?
- *Consider effects upon mission, equipment, personnel and environment*

→

What if it does happen? (So what?)
- *Consider nature of impact on each risk dimension*

Lack of Weather Observations
Lack of Aerodrome Forecast (TAF)
Tropical Depression
Tropical Storm
Tropical Cyclone / Typhoon
Snow Storm
Severe Winter Storm (Blizzard)
Freezing Precipitation
Drought
Prolonged Rainfall
Heavy Rainfall
Thunderstorms
Lightning
Tornados
Hail
Sandstorm / Duststorm
Low Cloud Ceiling
Restricted Visibility
Strong and/or Gusty Surface Winds
Strong Crosswinds
Tailwind on Approach and/or Landing
Unfavourable Upper Level Winds
Low Level Wind Shear
Icing
Low Level Turbulence
Turbulence in and around Thunderstorms
Clear Air Turbulence
Mountain Wave Turbulence
Wake Turbulence
High Density Altitude at Airport
Volcanic Eruption (VOLASH)
Tsunami affecting Airport
Floods / Flash floods and mudslides affecting airport / station
Extreme Low Surface Temperatures
Extreme High Surface Temperatures
Extreme Low Temperature at Altitude
Increased Temperature at Altitude
High altitude ice crystal icing
Visual Illusions
Unfavourable Space Weather

SOME POSSIBLE WEATHER HAZARDS

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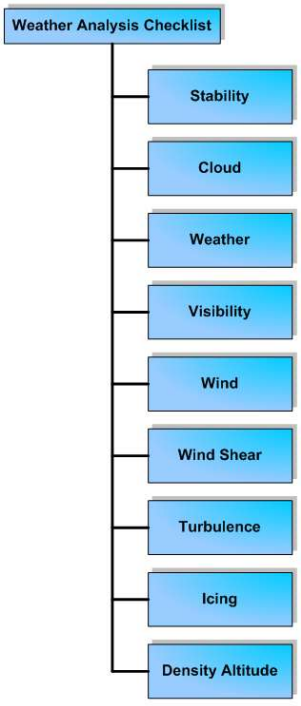
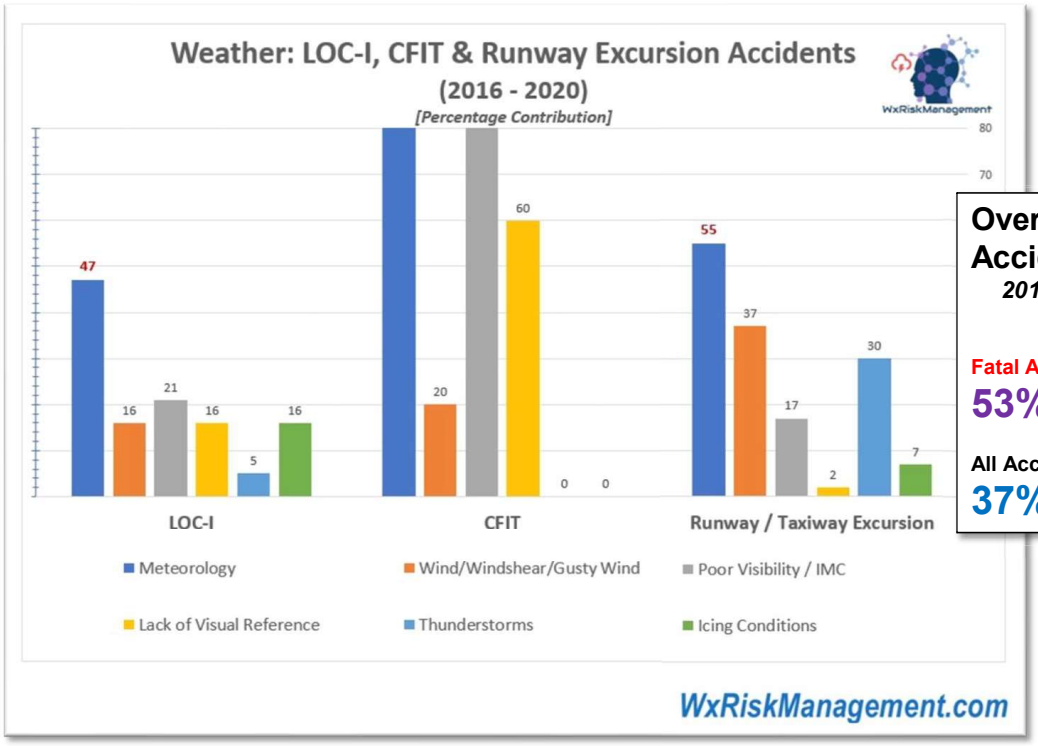
AVIATION WEATHER HAZARDS & CONCERNS

- Winds and Temperatures
  - (Terminal and Enroute)
- Wind shear
- Thunderstorms
- VOLASH
- Precipitation
- Icing
  - including High Altitude Ice Crystal Icing
- Density Height / Altitude
- Turbulence
- Visibility / Ceiling



(Dutcher, 2003)

WEATHER & ACCIDENTS – 2016-2020



Overall Accidents
2016 - 2020

Fatal Accidents:
53%

All Accidents:
37%

(Dutcher, 2021 based on IATA, 2021)

ROLE OF ITCZ IN LOC-I

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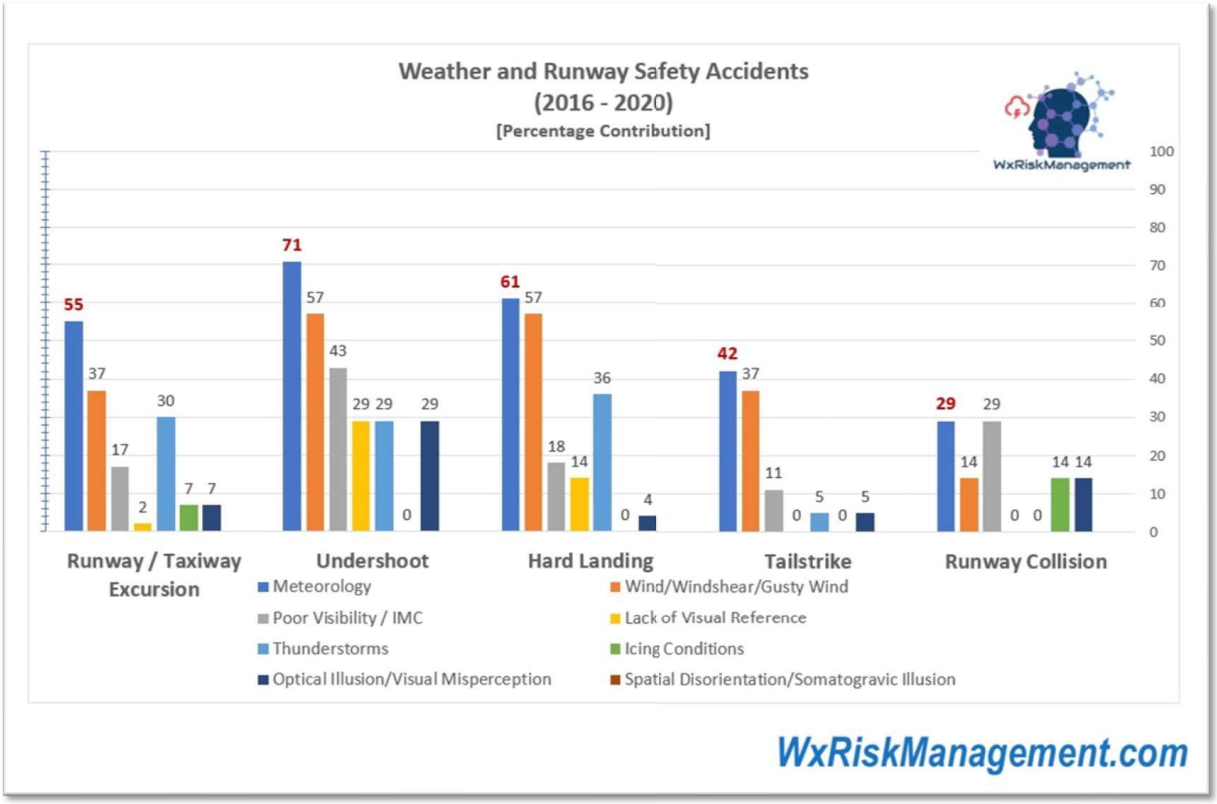
WEATHER & RUNWAY SAFETY ACCIDENTS



(Dutcher, 2021 based on IATA, 2021)

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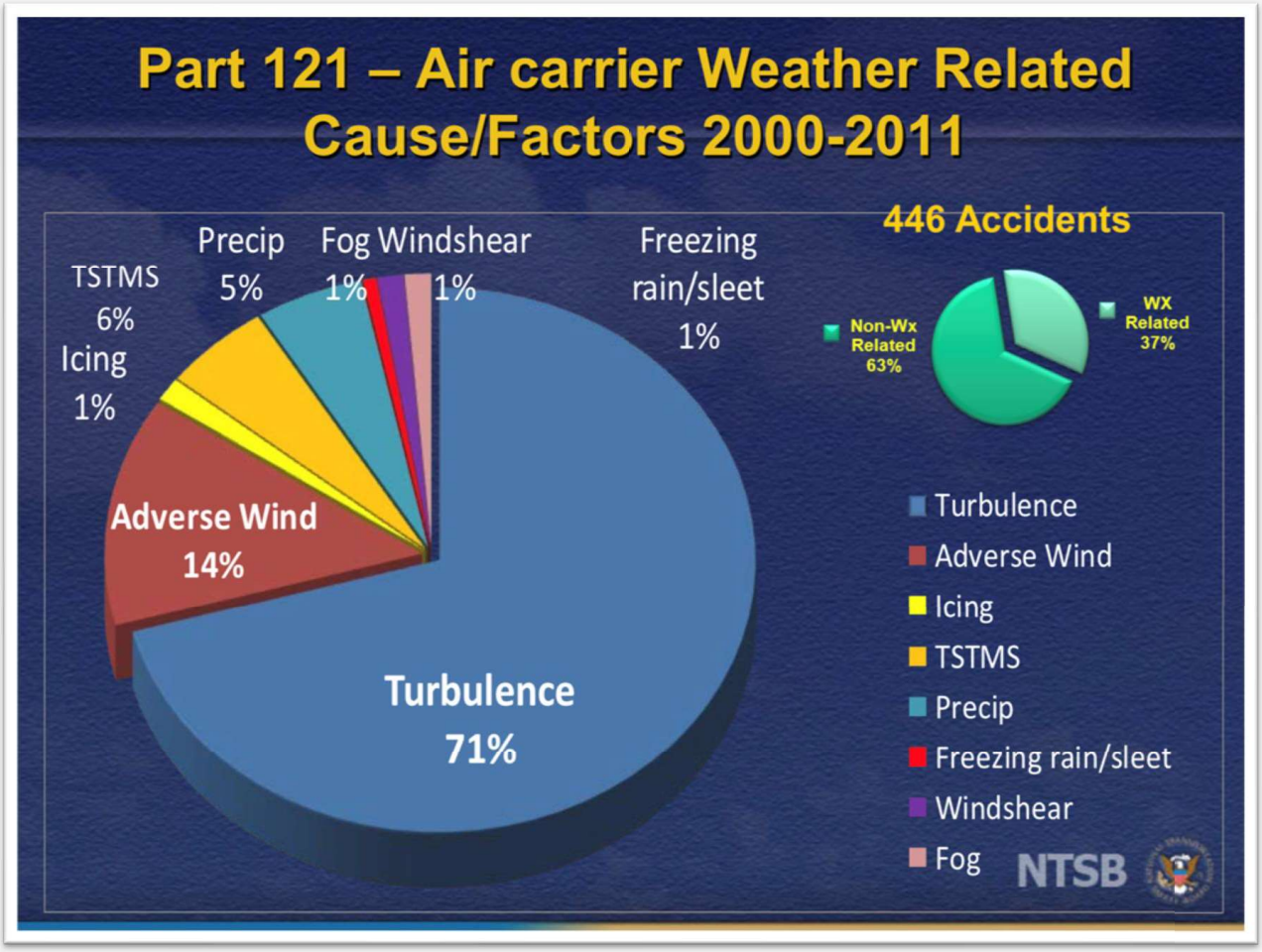

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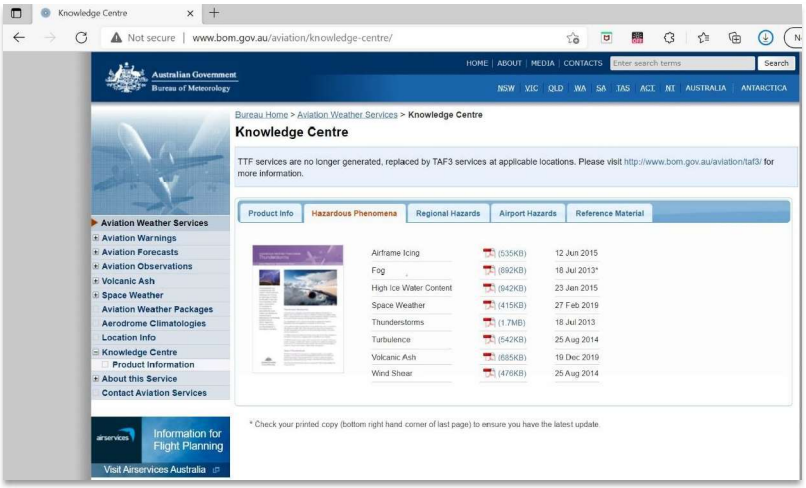
(NTSB presentation by Eick, n.d. – circa 2014)



Knowledge Centre (bom.gov.au)

INTERACTION RESOURCE

Australian Bureau of Meteorology – Knowledge Centre

Information on various Weather Hazards.

Prepared by John W. Dutcher (2021)

HAZARD ID

EXAMPLE

Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

Operation/Business Activity being assessed:

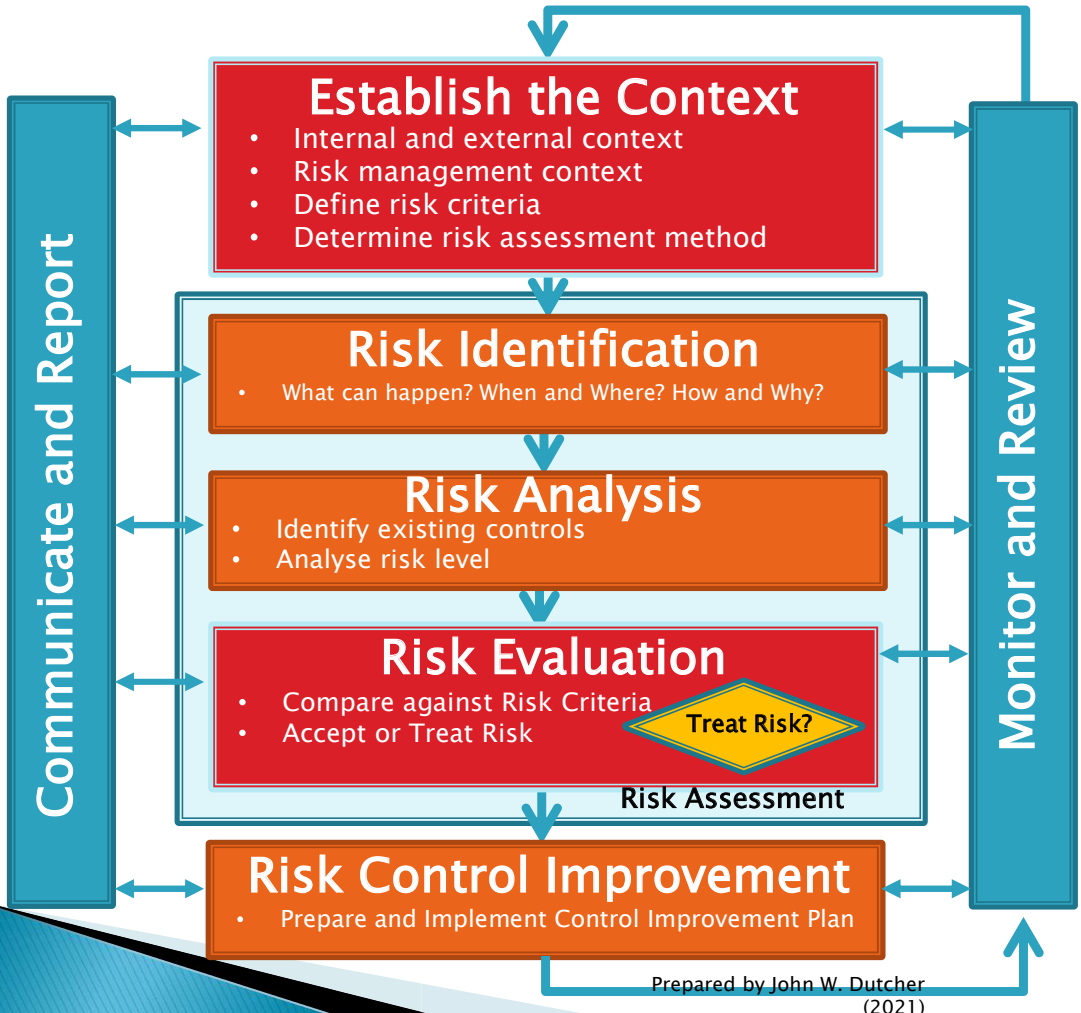
No.	Hazard(s)	Consequence	Likelihood	Current Controls (based on Hierarchy of Control)	Initial Risk Rating	Further Recommended Control (based on Hierarchy of Control)	Revised Risk Rating
1	Strong Surface Tailwind (>10 KT) resulting runway overrun – high-speed						

Prepared by John W. Dutcher (2021)

ASSESS RISKS

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)

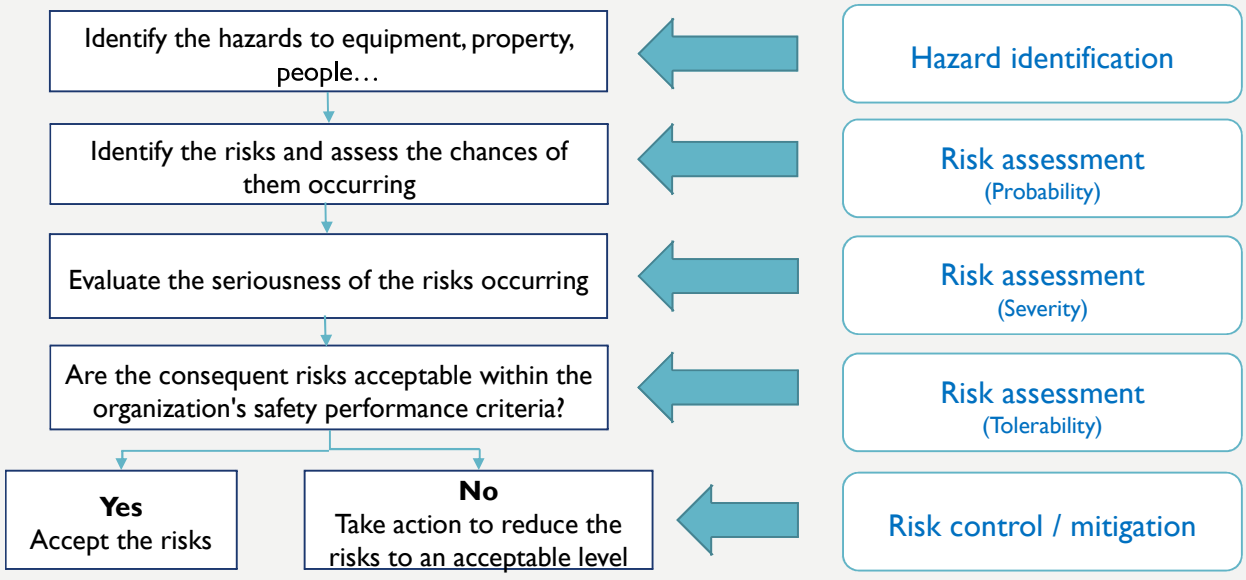


IMPORTANCE OF RISK ANALYSIS

Risk analysis is critical to…

- understanding the nature of the risk,
- the subsequent ranking and prioritisation of risks, and
- deciding on an appropriate treatment strategy.

RISK ASSESSMENT AT A GLANCE



STEP 3 – ANALYZING THE RISK

The aim of this step is to examine how significant the risk is to the Company.

A scale of measurement is often used to assist in communicating the importance of the risk and its potential impact.

The depth of analysis is determined by the complexity of the activity and the data available.

STEP 3 – ANALYZING THE RISK

- This step involves:
  - Identifying Existing Controls
  - Consider the Effectiveness of the Controls
  - Describing and Rate the Consequences of the Risk
  - Rating the Likelihood of the Consequence
  - Assigning a Risk Level, based on the Likelihood and Consequence

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DESCRIBING AND RATING THE CONSEQUENCES OF THE RISK

- ***Describe the Worst Foreseeable Case Scenario***. It may be possible to identify a sequence of events, possibly involving multiple independent failures (termed 'worst case scenario').

- The objective of a risk assessment is to identify the potential event representing a single failure, that is realistic and conservative (termed 'worst foreseeable case scenario').

KEY QUESTIONS WHEN ANALYSING RISKS

- What effective controls are already in place to manage this risk?

EXAMPLE

Risk Control Effectiveness Evaluation Guide

Test existing control design	Are our *controls* meeting the applicable laws, regulations and mandatory standards?
	Are our *controls* comparable with our peers or *accepted industry practice*?
	Has the environment changed and if so, are our *controls* still fit for purpose?
Test existing control operation	Do our monitoring activities indicate our *controls* are working?
	Do we have any outstanding action items from audits, reviews or investigations?
	In recent *occurrences*, did our *controls* work as intended?

Effective	Satisfactory	Needs Attention	Ineffective
Controls are well designed and are operating effectively and management monitoring and review of *controls* is established.	*Controls* are reasonably well designed and most aspects are operating effectively with some areas for improvement.	Certain *controls* are not well designed and/or are systematically not operating effectively.	Significant gaps in the design and operation of *controls*. No confidence that any degree of *control* is being achieved.

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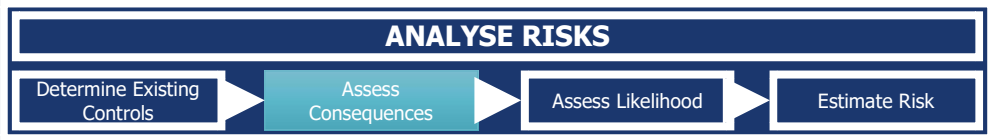
STEP 3 – ANALYZING THE RISK

- In order to calculate the risk level of an activity in the context of existing control measures the individual elements of the risk are first determined and then combined.
- The resultant risk level determines the required action in terms of risk mitigation.

KEY QUESTIONS WHEN ANALYSING RISKS

- What effective controls are already in place to manage this risk?
- What is the worst plausible consequence of the risk?



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ASSESSING CONSEQUENCE

Severity of occurrences		
Aviation Definition	***Meaning***	***Value***
Catastrophic	- Equipment destroyed - Multiple deaths	**A**
Hazardous	- A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely - Serious injury or death to a number of people. - Major equipment damage	**B**
Major	- A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency. - Serious incident. - Injury to persons.	**C**
Minor	- Nuisance / Operating limitations / Use of emergency procedures / Minor incident	**D**
Negligible	- Little consequences	**E**

Note: Rate the severity of consequences of the Worst Foreseeable Case Scenario ***in the absence of any additional corrective action*** **but** ***taking into account existing Controls and their effectiveness.***

Prepared by John W. Dutcher (2021)

RISK ACCEPTABILITY MATRIX

EXAMPLE

OUTCOME					CONSEQUENCE	LIKELIHOOD				
Safety of the Aircraft	People	Asset	Operations	Reputation		Likely to occur many times *(has occurred frequently)*	Likely to occur sometimes *(has occurred infrequently)*	Unlikely to occur, but possible *(has occurred rarely)*	Very unlikely to occur *(not known to have occurred)*	Almost inconceivable that the event will occur *(not known to have occurred)*
						>95% Probability	51–95% Probability	11–50% Probability	1–10% Probability	0.1–1% Probability
S	P	A	O	R		A Frequent	B Occasional	C Possible	D Unlikely	E Rare
No significant impact on aircraft related safety.	Slight health effect/injury.	Slight damage. *Up to 20% damage.*	Slight impact. No significant impact on operations.	Slight impact.	1 Negligible	M [1A]	L [1B]	L [1C]	VL [1D]	VL [1E]
Degrades or affects normal aircraft operational procedures or performance.	Minor health effect/injury.	Minor damage. *Up to 40% damage.*	Minor degradation; operation continues.	Limited impact.	2 Minor	M [2A]	M [2B]	L [2C]	L [2D]	VL [2E]
Partial loss of significant / major aircraft systems or results in abnormal flight operations procedure application.	Major health effect/injury.	Moderate damage. *Up to 60% damage.*	Significant impact. Maybe deemed unsuitable to continue.	Considerable impact.	3 Moderate	H [3A]	M [3B]	M [3C]	L [3D]	L [3E]
Complete loss of significant/major aircraft systems or results in emergency application of flight operations procedures.	Permanent Total Disability (PTD) or 1 to 3 fatalities.	Major damage. *Up to 80% damage.*	Major impact. Unsuitable to continue.	National impact.	4 Major	E [4A]	H [4B]	M [4C]	M [4D]	L [4E]
Aircraft/hull loss.	Multiple fatalities.	Extensive damage. *More than 80% damage.*	Operations ceased/suspend.	International impact.	5 Catastrophic	E [5A]	E [5B]	H [5C]	M [5D]	M [5E]
Risk Index Key:	VL Very Low	L Low Risk	M Moderate Risk	H High Risk	E Extreme Risk					

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IDENTIFYING EXISTING CONTROLS

- Identify existing Controls which will provide some protection against this against the risk.
  - Examples of defences include personal protective equipment, safety procedures and electronic warning devices such as TCAS and GPWS.
- **Assessment of the risk must take account of existing defences that will still be applicable in the hazard situation being considered.**
- If, for example, a changed procedure is being assessed where existing training will provide some protection against the hazard being considered, then this should be taken into account in assessing the consequences and likelihood.

KEY QUESTIONS WHEN ANALYSING RISKS

- What effective controls are already in place to manage this risk?
- What is the worst plausible consequence of the risk?
- What is the likelihood of this consequence occurring?

RISK PROBABILITY

- **Definition:** Probability – The chance that a situation of danger might occur.
- **Questions for assessing the probability of an occurrence:**
  - Is there a history of occurrences like the one being assessed, or is the occurrence an isolated event?
  - What other equipment, or similar type components, might have similar defects?
  - What number of operating or maintenance personnel must follow the procedure (s) in question?
  - How frequently is the equipment or procedure under assessment used?

RISK PROBABILITY

Probability of Occurences		
Qualitative Definition	**Meaning**	**Value**
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur some times (Has occurred infrequently)	4
Remote	Unlikely, but possible to occur (Has occurred rarely)	3
Improbable	Very unlikely to occur (Not known has occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Note: ***It is the likelihood of the consequence being rated, not the likelihood of the hazard.***

RISK ACCEPTABILITY MATRIX

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STEP 4 – EVALUATING THE RISK

- Risk evaluation involves comparing the level of risk found during the analysis process with previously established risk criteria, and deciding whether these risks can be accepted. If not, the risk is prioritized for treatment.

- What to do:
  - Compare the level of risk against the risk criteria set in Step 1.
  - Decide if the risk is acceptable or does it require treatment to reduce the level of risk.
  - Develop a prioritized list of risks for treatment.

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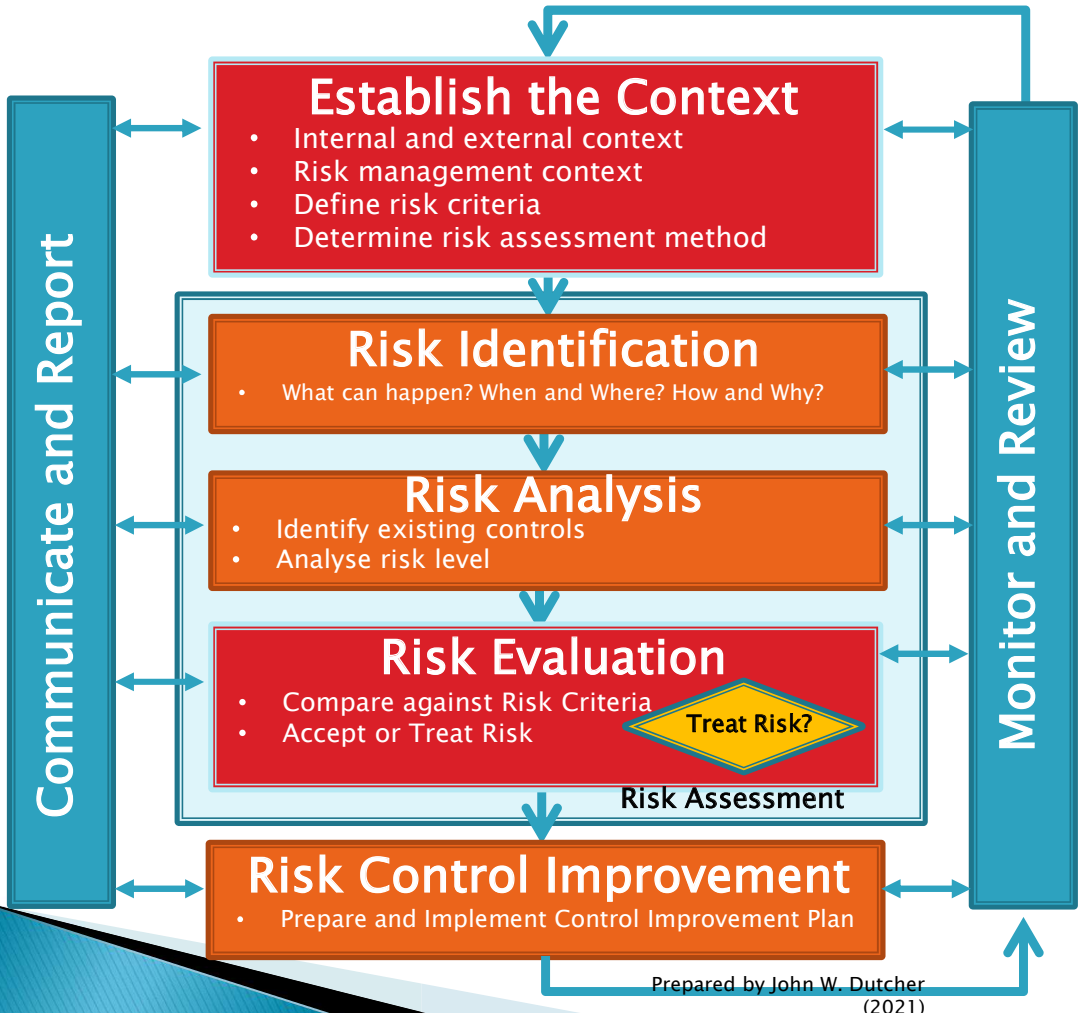

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STEP 4 – EVALUATING THE RISK

- **Review**
- • ***What is the acceptable level of risk for this activity?***
- • What level of risk delegated and authorized to accept?
- • If I cannot accept the risk, whom can I refer it to for action?
- • What is the priority of the risks?
- • Will any risk or combination of risks terminate the operations?
- • Is immediate action required?
- • Who do I communicate the results to?

WHAT IS RISK EVALUATION?

- We evaluate analysed risks against the initial risk criteria to determine which risks:
  - Are acceptable (tolerable), and
  - Require treatment
- We then prioritise risks to be treated, regarding their overall risk level or severity

RISK ACCEPTABILITY MATRIX

Risk Probability	Severity				
	Catastrophic (A)	Hazardous (B)	Major (C)	Minor (D)	Negligible (E)
5 - Frequent	5A	5B	5C	5D	5E
4 - Occasional	4A	4B	4C	4D	4E
3 - Remote	3A	3B	3C	3D	3E
2 - Improbable	2A	2B	2C	2D	2E
1 - Extremely improbable	1A	1B	1C	1D	1E

RISK ACCEPTABILITY MATRIX

EXAMPLE

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COMPARE EACH AGAINST RISK CRITERIA

- Is the risk level tolerable against the risk criteria?
  - ***Target Level of Risk = Acceptable Risk? Or ALARP?***
  - ***Usually already defined in your SMS Manual***
- Is the risk As Low As Reasonably Practical (ALARP)?
  - Are there additional controls or remedies I can apply to reduce the risk level?

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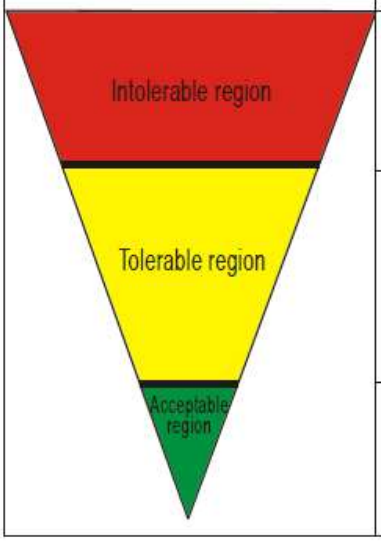
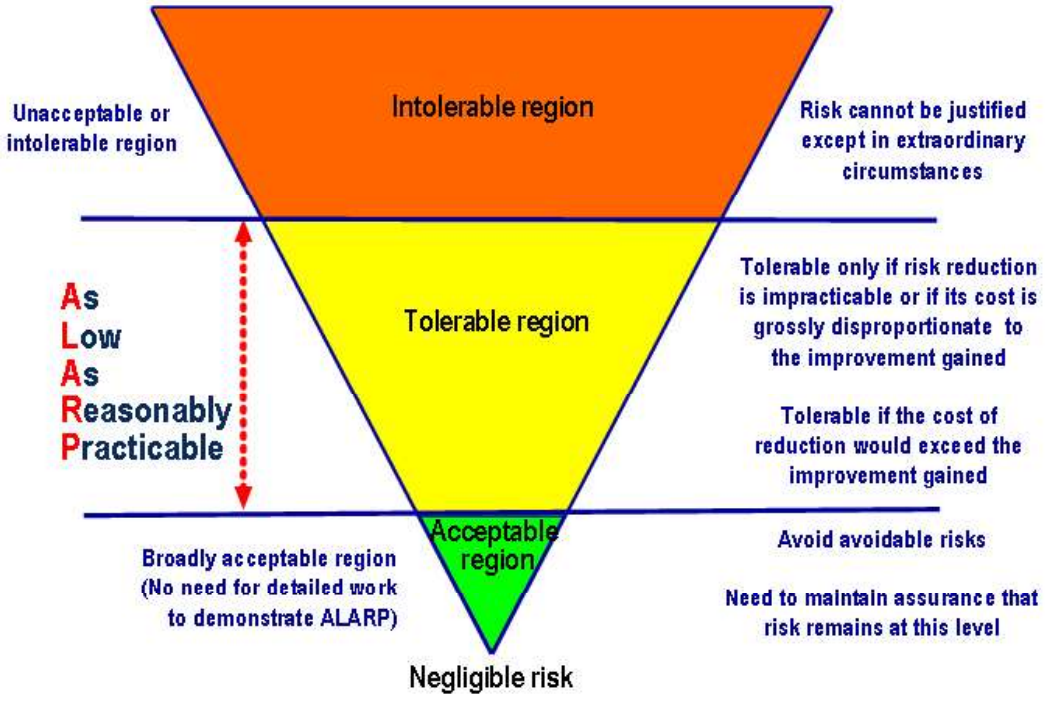
ACCEPTANCE CRITERIA / RISK TOLERABILITY MATRIX

Suggested criteria	Assessment risk index	Suggested criteria
	**5A, 5B, 5C, 4A, 4B, 3A**	Unacceptable under the existing circumstances
	5D, 5E, 4C, 4D 4E, 3B, 3C, 3D 2A, 2B, 2C, 1A	Acceptable based on risk mitigation. It may require management decision.
	3E, 2D, 2E 1B, 1C, 1D, 1E	Acceptable

ALARP PRINCIPLE



ACCEPTABILITY ASSESSMENT INDEX

Assessment Risk Index	Suggested Criteria
5A, 5B, 5C, 4A, 4B, 4C, 3A	Unacceptable under the existing circumstances
5D, 5E, 4D, 3B, 3C, 2A, 2B	Risk control/mitigation requires management decision
4E, 3D, 2C, 1A, 1B	Acceptable after review of the operation
3E, 2D, 2E, 1C, 1D, 1E	Acceptable

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RISK ACCEPTANCE DECISION

EXAMPLE

Risk Level	Risk Index	Acceptability / Action Required
5A, 5B, 4A	Extreme Risk	**STOP OPERATION OR PROCESS IMMEDIATELY** Unacceptable under the existing circumstances. Do not permit any operation until sufficient control measures have been implemented to reduce the risk to an acceptable level. Senior management approval required.
5C, 4B, 3A	High Risk	**CAUTION** Ensure that risk assessment has been satisfactorily completed and declared preventive controls are in place. Senior management approval of risk assessment before commencement of the operation or process.
5E, 5D, 4D, 4C, 3C, 3B, 2B, 2A, 1A	Moderate Risk	Perform or review risk mitigation as necessary. Departmental approval of risk assessment.
4E, 3E, 3D, 2D, 2C, 1C, 1B	Low Risk	Risk mitigation or review is optional.
2E, 1E, 1D	Very Low Risk	Acceptable as is. No risk mitigation required.

Prepared by John W. Dutcher (2021)

SAFETY RISK ACCEPTANCE - REQUIREMENTS FOR ESCALATING RISKS

EXAMPLE

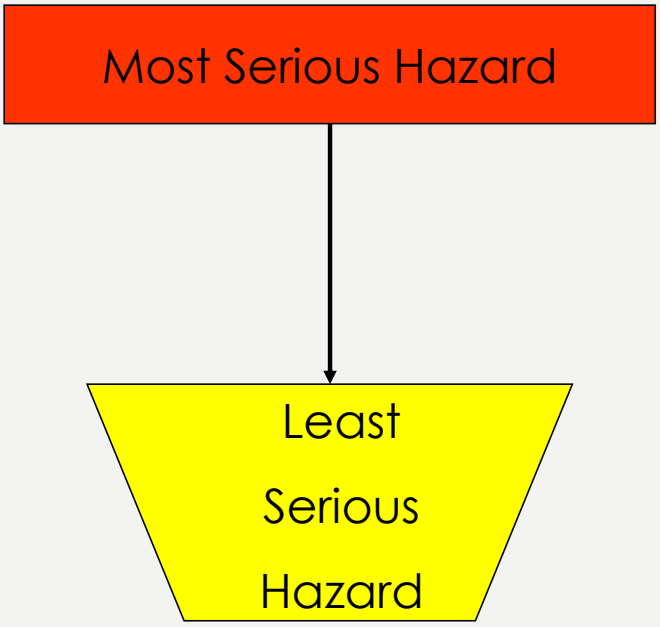
Resultant Risk Level	Very Low	Low	Moderate	High	Extreme
Escalate and Endorsement	Manager	Manager	Head of Dept.	COO, DSQS, and Head(s) of Dept.	Chief Executive Officer

SET RISK PRIORITIES

- Use risk matrix as guidance
- How does each risk compare with others?
  - Do "sanity check"
- Prioritise the risks

COMPLETE THE ASSESSMENT

- **The Risk Priority List**



By ranking the hazards, we can work on them on a "worst-first" basis.

This is necessary because resources are always limited and should always be applied to achieve the maximum benefit.

SET RISK PRIORITIES

1	???
2	!!!!!!!! (Treat this one second)
3	???
4	!!!!!!!!!!!! (Treat this one first!)
5	???

EXAMPLE

Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

Section 3: Risk Treatment Action Plan (RTAP) (Note: A combination of risk control measures may be required to decrease risk as far as practicable)

You must always aim to eliminate a hazard, which is the most effective control. If this is not reasonably practicable, you must minimise the risk by working through the other alternatives in the hierarchy.

1. Can you stop doing the task or part of the task to eliminate the risk?	☐ Yes (document below how this will be achieved)	☐ No, or only part of it

2. Can you eliminate or reduce the risk by doing one or more of these things?
(Document the actions below and consider what information, instruction, training and supervision may be necessary to make these controls work properly.)

☐	a) altering the workplace	☐	d) changing the objects used in the task, or
☐	b) altering the environmental conditions	☐	e) using mechanical aids
☐	c) altering the systems of work		

Short-term (immediately to within one week)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

Medium-term (from one week to three months)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

Long-term (greater than three months)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

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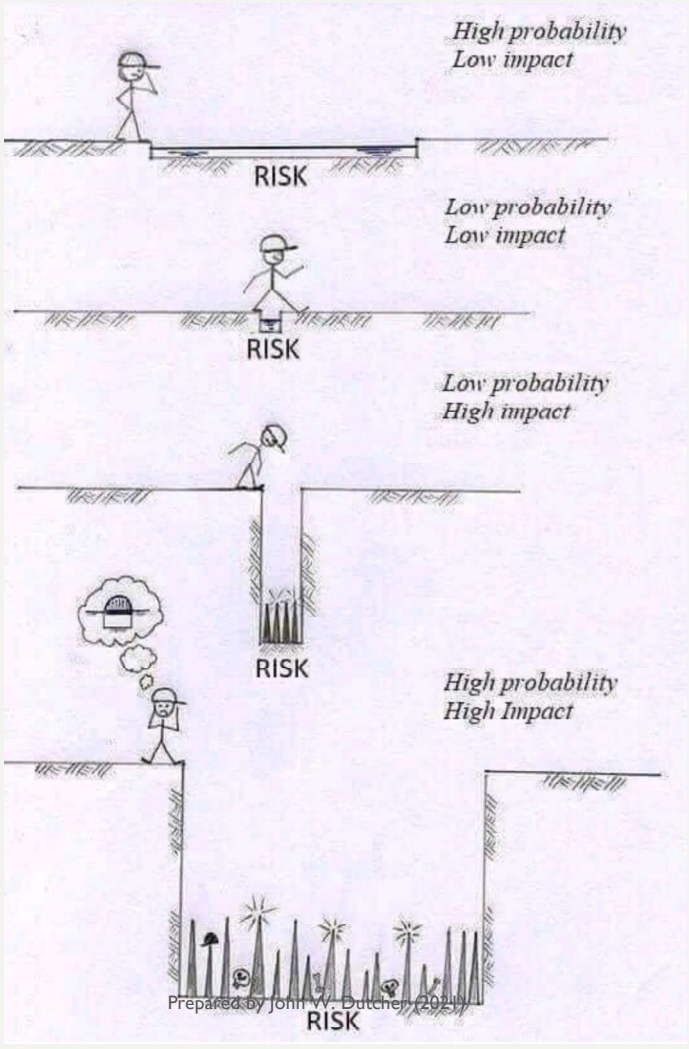

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03

WEATHER RISK CONTROL

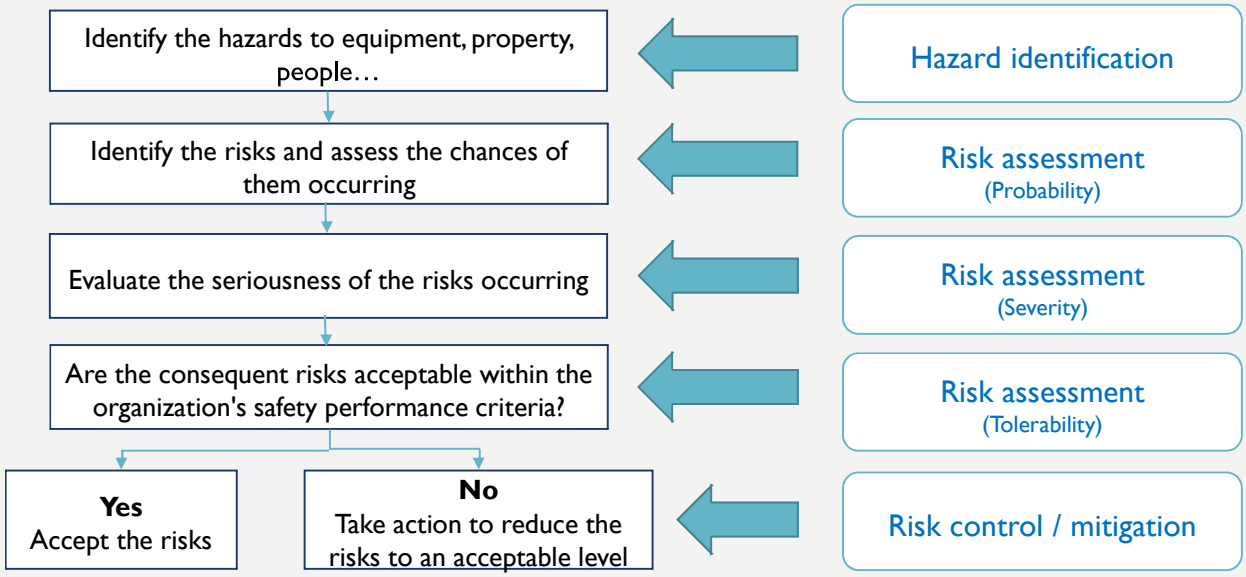
Prepared by John W. Dutcher (2021)

TREAT RISKS

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)

RISK ASSESSMENT AT A GLANCE



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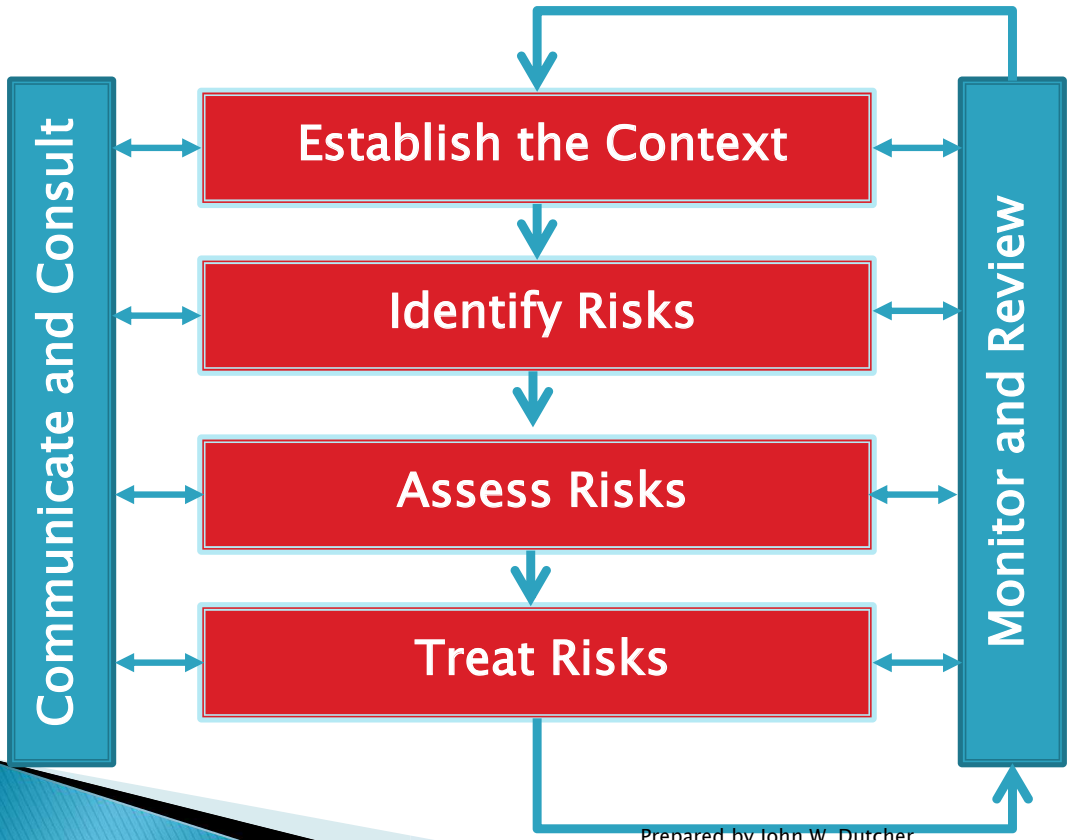
Weather Risk Management Process



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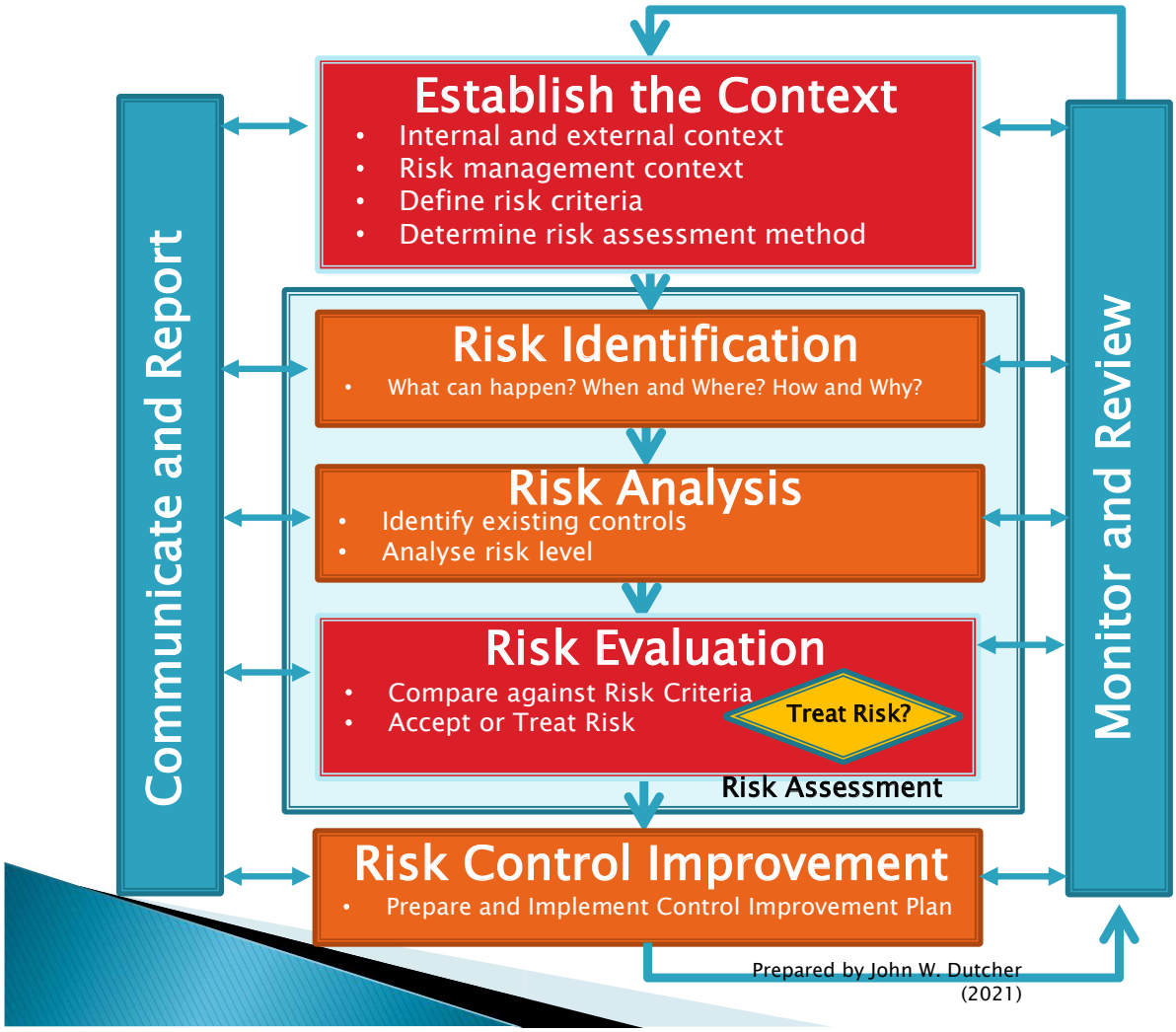
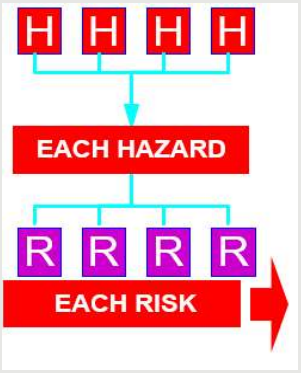


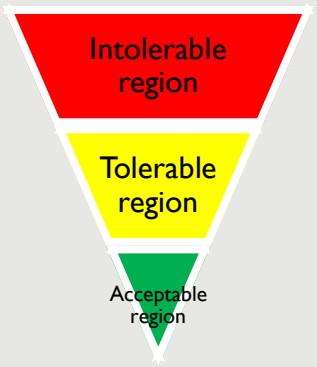
RISK CONTROL / MITIGATION

- **Definition:** Mitigation – Measures to eliminate the potential hazard or to reduce the risk probability or severity (Risk mitigation = Risk control)
- **Mitigation strategies:**
  - Avoidance – The operation or activity is cancelled because risks exceed the benefits of continuing the operation or activity.
  - Reduction – The frequency of the operation or activity is reduced, or action is taken to reduce the magnitude of the consequences of the accepted risks.
  - Segregation of exposure – Action is taken to isolate the effects of risks or build-in redundancy to protect against it, i.e., reduce the severity of risk.

RISK MITIGATION AT A GLANCE

Hazard identification and risk management	Assessment of the defenses within the safety system	Control and mitigation of the risks	Accepting the mitigation of the risks

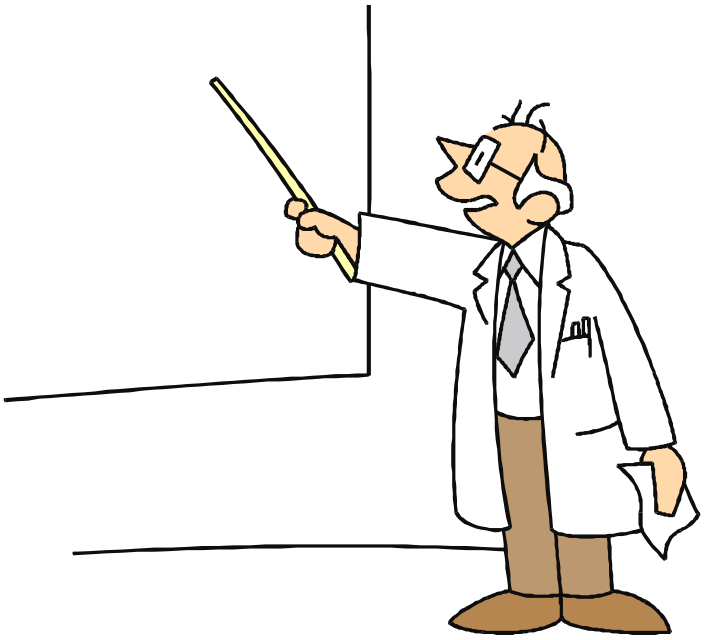




- Does the mitigation address the hazard?
- Does it address the risks?
- Is it effective?
- Is it appropriate?
- Is additional or different mitigation warranted?
- Do the mitigation strategies generate additional risks?

WHAT IS A RISK TREATMENT?

Any action or resource that, when applied to a risk, reduces its likelihood and/or consequence



RISK CONTROL OPTIONS

Approaches to risk control

- Accept
- Reduce
- Avoid
- Spread
- Transfer

FIRST—IDENTIFY RISK CONTROL OPTIONS

- Start with highest risk hazards identified.
- Refer to the list of possible causes in Step 2.
- Use one or a blend of controls from the risk control options list.

WHAT IS RISK CONTROL?

- A process in which risks are **reduced or maintained** within specified levels. It occurs after Risk Assessment.
- Helps you determine what **detection or other controls** are already in place to maintain the risk within specified levels.
- Helps you determine whether these controls give **assurance** that the risk is adequately controlled & no further controls are required.
- Helps you determine what **additional actions or controls** are needed to reduce the risk or maintain it within specified levels.

RISK CONTROL

- Risk Control work also helps determine:
  - Critical Control Points/Phases (or Critical Weather Parameters);
  - How they will be monitored; and
  - What level of Qualification & Competency are required.

WEATHER RISK CONTROLS

- *Engineering defences.* Physically prevent a hazard from causing harm (i.e. 'engineering fixes')
- *System defences.* Control hazards by specifying procedures to be followed, such as a company policy regarding operations near turbulence, TS, recovery procedures.
- *Human defences.* Are the actions, competence and expertise required by individuals to prevent hazards from being realised in the first place.

RISK CONTROL SYSTEM (RCS)

- Any physical or procedural method designed to mitigate risk.
- RCSs are like mini RMSs, containing all the elements of a management system.
  - Turbulence
  - Thunderstorms
  - Typhoons
  - Fog
  - Low Vis and Ceiling
  - Wind
  - Wind Shear
  - Etc.

FLYING OPERATIONS

HEAVY WEATHER

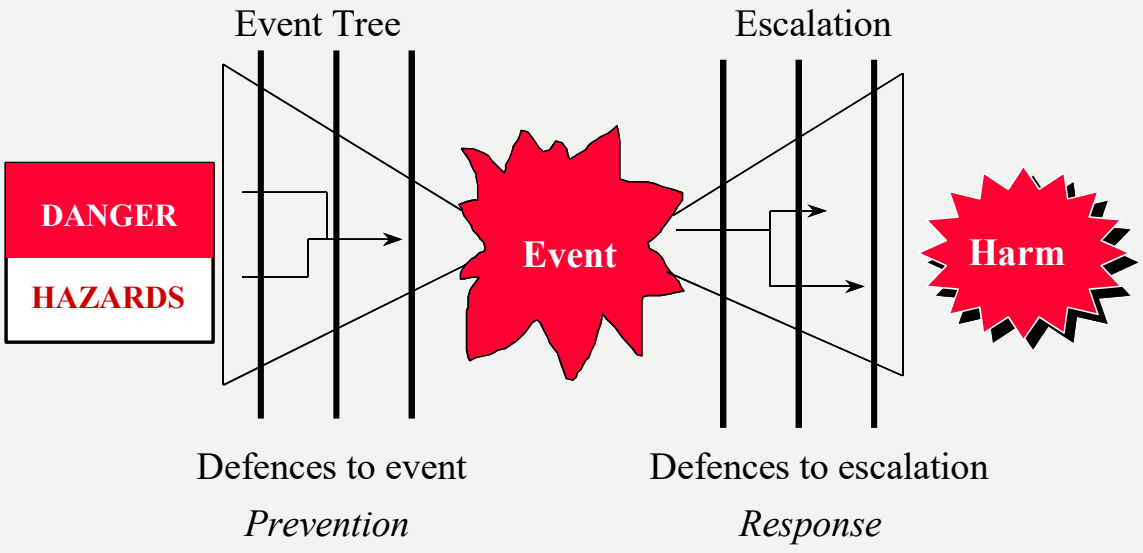
Weather occurrences are not "just the cost of doing business" – their risks can be managed, says John Dutcher.

(Dutcher, 2005 – Flight Safety Australia)

RISK CONTROL SYSTEM (RCS)

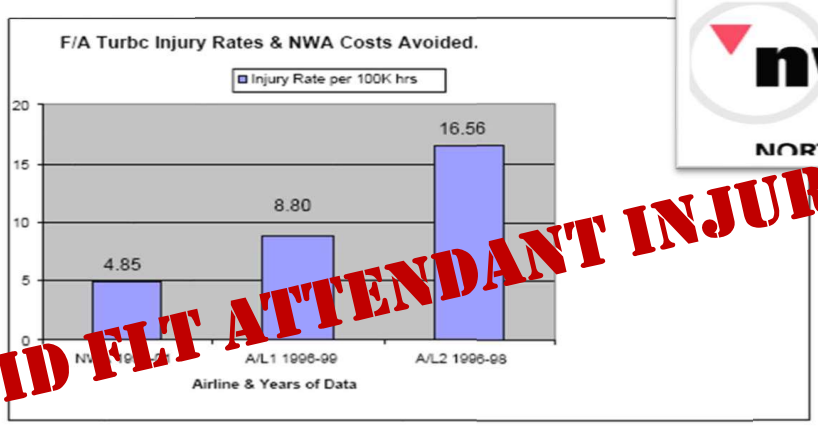
- Has a policy that sets out the vision and demonstration of management commitment.
- The specific organisational arrangements required to implement and operate the program are described.
- The objectives of the RCS are specified so that the effectiveness of the program can be evaluated.
- Audit arrangements are also detailed for each RCS.

BOW TIE MODEL



MANAGING WEATHER

TURBULENCE PLOT (TP) SYSTEM



AVOID FLT ATTENDANT INJURIES

F/A Turbc Injury Rates & NWA costs Avoided

Airline & Yrs	Injury Rate per 100K hrs	Cost/yr avoided	Total Costs avoided
NWA 1996-01	4.85	Base	Base
A/L1 1996-99	8.80	$ 447,426	$ 1,789,704
A/L2 1996-98	16.56	$ 1,325,299	$ 3,975,897

Assume Average Cost per F/A Injury at A/L1 & A/L2 is $10K

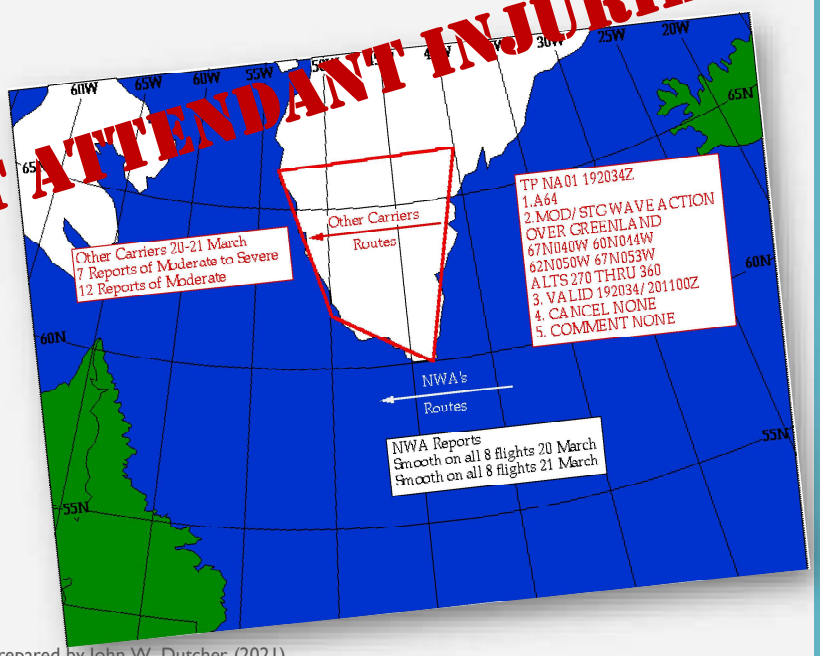
Prepared by John W. Dutcher (2021)

(Adapted from Fahey, 2007)

MTN WAVE FORECASTS & AVOIDANCE

- ✓ Product Used by Dispatchers & Pilots
- ✓ Use Designated Mtn Wave Deviation Routes

AVOID FLT ATTENDANT INJURIES



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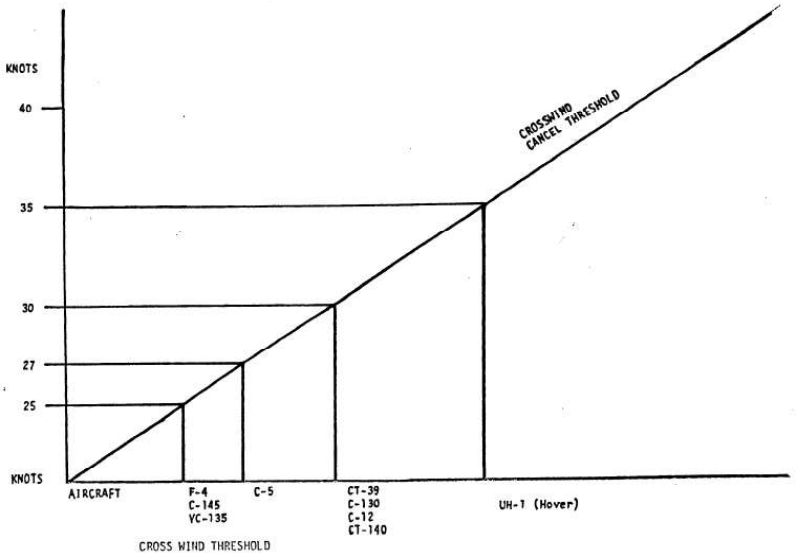
(Adapted from Fahey, 2007)

CROSS-WIND CANCEL THRESHOLD



Prepared by John W. Dutcher (2021)

EASA SIB – 2015-13

Safety Management of Flight Operations in Adverse Convective Weather and the Inter-Tropical Convergence Zone

Competency of personnel:

- Effective detection and resolution of lack of knowledge, deficient skills and inappropriate attitudes of pilots, dispatchers, maintenance personnel and safety officers as regards their proficiency to ensure safe flight operations in adverse convective weather and the ITCZ;
- Adequate initial, recurrent, route-specific or seasonal refresher training with regard to the specific geographical areas of operation associated with the ITCZ.

EASA Safety Information Bulletin

SIB No.: 2015-13
Issued: 29 July 2015

Subject: Safety Management of Flight Operations in Adverse Convective Weather and the Inter-Tropical Convergence Zone

Ref. Publications: American Institute of Aeronautics and Astronautics (AIAA) Paper No 2014-0612, NF1676L-16719 "Preliminary Analysis of Aircraft Loss of Control Accidents: Worst Case Precursor Combinations and Temporal Sequencing".

National Aeronautics and Space Administration (NASA) Paper No NF1676L-11047 "Aircraft Loss-of-Control Accident Analysis" and Paper No 00099, NF1676L-11771 "Aircraft Loss-of-Control: Analysis and Requirements for Future Safety-Critical Systems and their Validation".

European Aviation Safety Plan 2014-2017.

European Commission Regulation (EU) No 965/2012 on Air Operations, Part-ORO – see European Flight Standards Implementing Rules.

International Civil Aviation Organization (ICAO) Annex 19 "Safety Management"; ICAO Doc 9859 "Safety Management Manual"; ICAO 2014 Safety Report; ICAO Doc 10011 "Manual on Aeroplane Upset Prevention"; ICAO Doc 8335 "Manual of Procedures for Operations Inspection, Certification and Continued Surveillance"; ICAO Doc 7192 "Training Manual - Part F1 - Meteorology for Air Traffic Controllers and Pilots"; ICAO Doc 7192 "Training Manual - Part D3 - Flight Operations Officers/Flight Dispatchers".

Federal Aviation Administration (FAA) Advisory Circular No AC 00-24C "Thunderstorms" and No AC 91-70A "Oceanic and International Operations".

European Authorities Coordination Group on Flight Data Monitoring (EAFDM) – "Developing standardised FDM-based indicators (Dec. 2013)".

United Kingdom Civil Aviation Authority Aeronautical Information Circular AIC No. P 056/2010 "The Effect of Thunderstorms and Associated Turbulence on Aircraft".

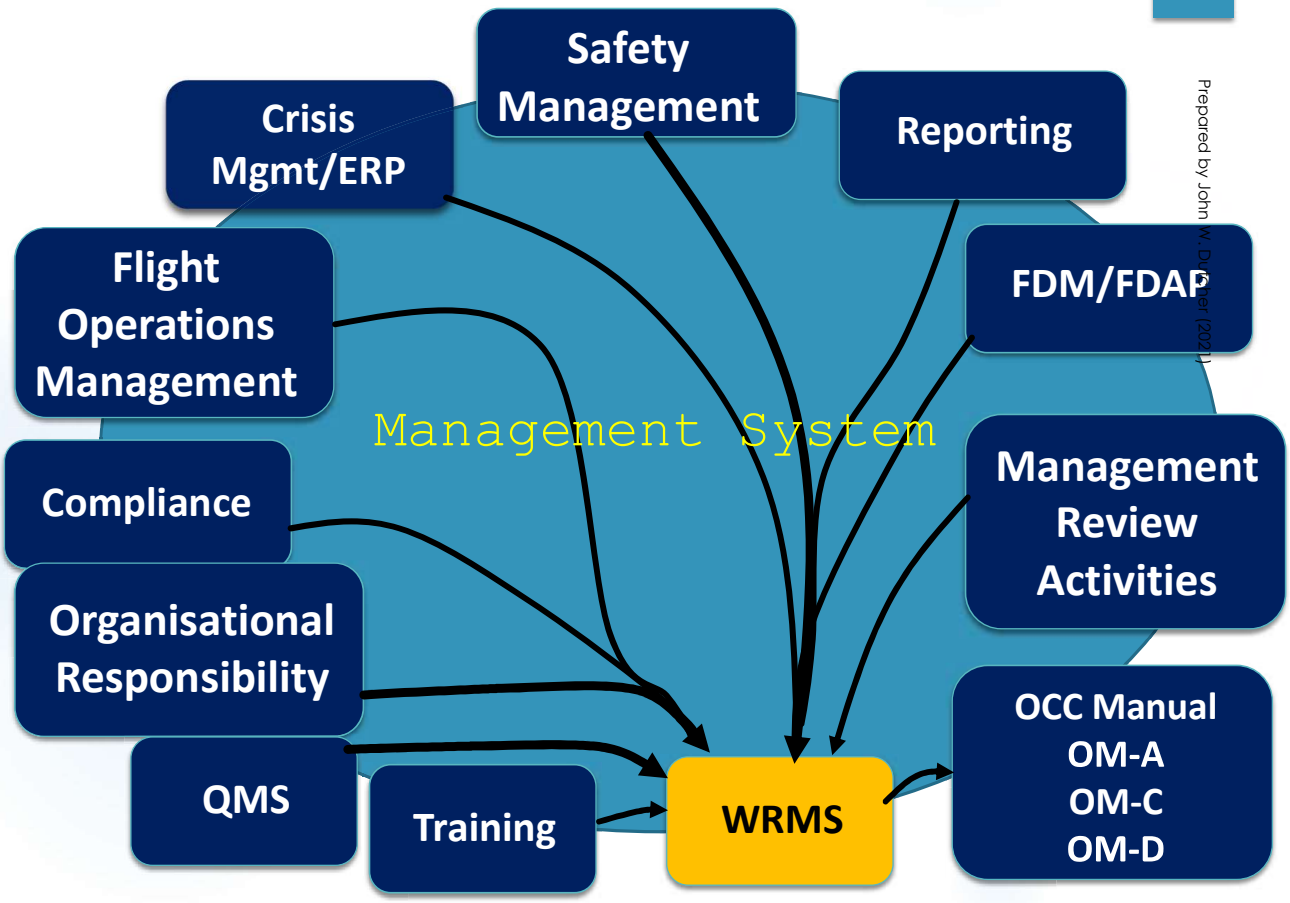
International Air Transport Association (IATA) Safety Report 2014, 51st Edition (April 2015).

EASA, 2015 – SIB 2015-13

Prepared by John W. Dutcher (2021)

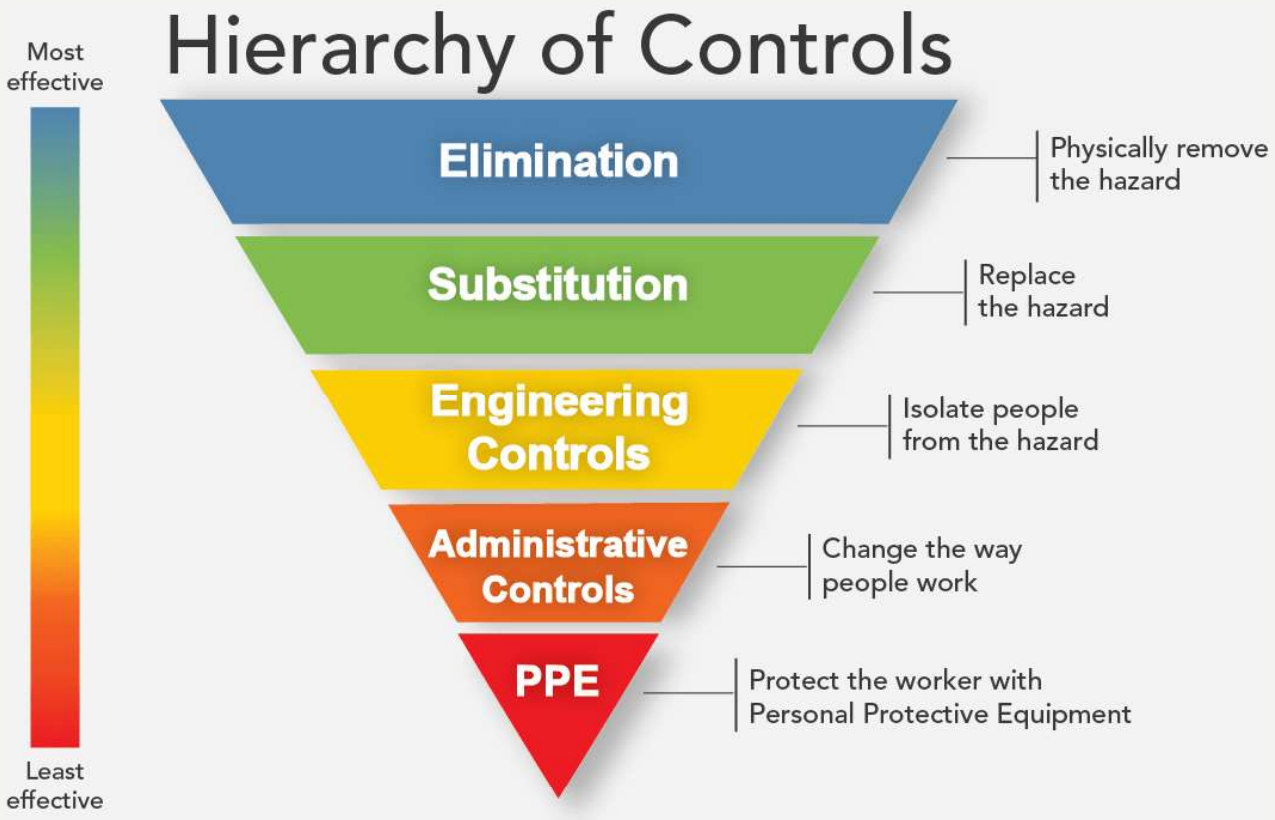
WRMS as part of Management System

[Airline Example]



IS THERE A "BEST" RISK CONTROL?

Most Desirable	**Eliminate** Remove the risk or hazard. **Substitute** Use different materials/process/method to make safer. **Engineer/Isolate** Ensure by design that if an incident occurs its likelihood and/or consequences are limited and controlled. Isolate people from the high risk area, e.g. barriers, etc.
Less Desirable	**Administration Use of policies and standards.** Procedures, instruction and supervision. Training, briefing and drills, to reduce the likelihood of an incident. **Personal Protective Equipment** Reduce consequences only.



RISK CONTROLS

THE SAFETY ORDER OF PRECEDENCE

Eliminate The Hazard

- The preferred solution - a non-existent hazard cannot cause an accident.

Control The Hazard

- The most common response
- Reduce the severity of the effect or the probability of occurrence of an accident resulting from a hazard.

RISK CONTROLS

THE SAFETY ORDER OF PRECEDENCE

- **Provide Alerts & Warnings**
  - Not an engineering solution
  - Does nothing to control the hazard
  - Requires action by an individual
- **Establish Procedural Controls**
  - Does not control hazard
  - Remains in place without presence of a hazard **TRAINING IS ESSENTIAL!**
- **Accept Residual Risk**

CONTROL DECISIONS

CHARACTERISTICS OF A GOOD DECISION MAKING PROCESS

- Promptly get decisions to the right decision maker
- Create a trail of accountability
- Make risk decisions at the appropriate level
- Decisions are timely

RISK ACCEPTABILITY MATRIX

EXAMPLE

OUTCOME					CONSEQUENCE	LIKELIHOOD				
Safety of the Aircraft	People	Asset	Operations	Reputation		Likely to occur many times *(has occurred frequently)*	Likely to occur sometimes *(has occurred infrequently)*	Unlikely to occur, but possible *(has occurred rarely)*	Very unlikely to occur *(not known to have occurred)*	Almost inconceivable that the event will occur *(not known to have occurred)*
						>95% Probability	51–95% Probability	11–50% Probability	1–10% Probability	0.1–1% Probability
S	P	A	O	R		A Frequent	B Occasional	C Possible	D Unlikely	E Rare
No significant impact on aircraft related safety.	Slight health effect/injury.	Slight damage. *Up to 20% damage.*	Slight impact. No significant impact on operations.	Slight impact.	1 Negligible	M [1A]	L [1B]	L [1C]	VL [1D]	VL [1E]
Degrades or affects normal aircraft operational procedures or performance.	Minor health effect/injury.	Minor damage. *Up to 40% damage.*	Minor degradation; operation continues.	Limited impact.	2 Minor	M [2A]	M [2B]	L [2C]	L [2D]	VL [2E]
Partial loss of significant / major aircraft systems or results in abnormal flight operations procedure application.	Major health effect/injury.	Moderate damage. *Up to 60% damage.*	Significant impact. Maybe deemed unsuitable to continue.	Considerable impact.	3 Moderate	H [3A]	M [3B]	M [3C]	L [3D]	L [3E]
Complete loss of significant/major aircraft systems or results in emergency application of flight operations procedures.	Permanent Total Disability (PTD) or 1 to 3 fatalities.	Major damage. *Up to 80% damage.*	Major impact. Unsuitable to continue.	National impact.	4 Major	E [4A]	H [4B]	M [4C]	M [4D]	L [4E]
Aircraft/hull loss.	Multiple fatalities.	Extensive damage. *More than 80% damage.*	Operations ceased/suspend.	International impact.	5 Catastrophic	E [5A]	E [5B]	H [5C]	M [5D]	M [5E]
Risk Index Key:	VL Very Low	L Low Risk	M Moderate Risk	H High Risk	E Extreme Risk					

Prepared by John W. Dutcher (2021)

HAZARD ID

EXAMPLE

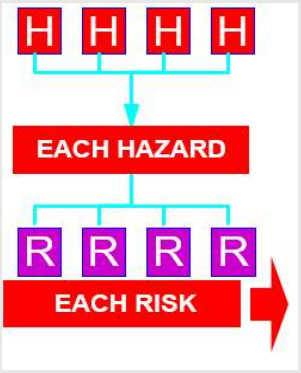
Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

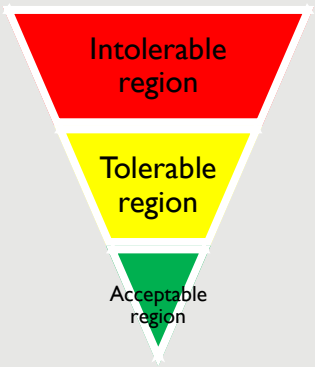
Operation/Business Activity being assessed:

No.	Hazard(s)	Consequence	Likelihood	Current Controls (based on Hierarchy of Control)	Initial Risk Rating	Further Recommended Control (based on Hierarchy of Control)	Revised Risk Rating
1	Strong Surface Tailwind (>10 KT) resulting runway overrun – high-speed	4 Major	B Occasional	Wind Sensor near centre of runway at MET enclosure. METAR/SPECI reporting. MET Updates to ATC. ATC Update ATIS for Pilots. Pilots have tailwind limit for aircraft. Pilots can conduct Go-Around. Airport/ATS ERP	4B High Risk	Wind Sensors at various locations at the airport (correct installation, calibration/maintenance) Change Runway Procedures Avoid Close Vectoring to Final MET and ATS Weather Refresher	

RISK MITIGATION AT A GLANCE

Hazard identification and risk management	Assessment of the defenses within the safety system	Control and mitigation of the risks	Accepting the mitigation of the risks





- Does the mitigation address the hazard?
- Does it address the risks?
- Is it effective?
- Is it appropriate?
- Is additional or different mitigation warranted?
- Do the mitigation strategies generate additional risks?

HAZARD ID

EXAMPLE

Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

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SAFETY RISK ACCEPTANCE - REQUIREMENTS FOR ESCALATING RISKS

EXAMPLE

Resultant Risk Level	Very Low	Low	Moderate	High	Extreme
Escalate and Endorsement	Manager	Manager	Head of Dept.	COO, DSQS, and Head(s) of Dept.	Chief Executive Officer

GUIDELINES IN CHOOSING CONTROLS

- Select the option yielding the most mission supportive level of risk—*not the lowest risk option.*
- Avoid risk control combinations that are incompatible
- Use risk controls that re-enforce each other.
- Evaluate full costs versus full benefits.
- Chose redundant controls (i.e, Defences in Depth)

GUIDELINES IN CHOOSING CONTROLS

Keep assessment separate from decision	Don't present assumptions as facts	Target decisions on worst first
Emphasize the operational impact	Ensure everyone understands the decision	Consider the unintended consequences
Use own Knowledge and experience	Development of Data bases	Address uncertainty

IMPLEMENTATION MODEL

- Identify the key tasks
- Assign the key tasks to the correct level of management
- Measure performance
- Reward correct behavior/correct incorrect behavior

RISK CONTROL LOG

- Company Safety Risk Register
- Or standlone Company Weather Risk Register
- Build accountability for safety

HAZARD ID

EXAMPLE

Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

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RISK CONTROL/MITIGATION LOG

Risk reference	Generic hazard	Risks description	Current measures to reduce risks and risk index	Further actions to reduce risks and resulting risk index	Responsibility
			Risk index: Risk tolerability:	Risk index: Risk tolerability:	

EXAMPLE

Hazard Identification, Risk Assessment and Control (HIRAC) Worksheet

Section 3: Risk Treatment Action Plan (RTAP) (Note: A combination of risk control measures may be required to decrease risk as far as practicable).

You must always aim to eliminate a hazard, which is the most effective control. If this is not reasonably practicable, you must minimise the risk by working through the other alternatives in the hierarchy.

1. Can you stop doing the task or part of the task to eliminate the risk?	☐ Yes (document below how this will be achieved)	☐ No, or only part of it

2. Can you eliminate or reduce the risk by doing one or more of these things?
(Document the actions below and consider what information, instruction, training and supervision may be necessary to make these controls work properly.)

☐	a) altering the workplace	☐	d) changing the objects used in the task, or
☐	b) altering the environmental conditions	☐	e) using mechanical aids
☐	c) altering the systems of work		

Short-term (immediately to within one week)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

Medium-term (from one week to three months)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

Long-term (greater than three months)

No. *(from Risk Assessment)*	Action Required	Person Responsible	Completion Date	Reviewed Date	Action Completed	Verify implementation / Treatment Effectiveness

WHAT IS WEATHER RISK MANAGEMENT?

- The **combination** of **Risk Assessment** & **Risk Control**, with mechanisms for Periodic Review and Risk Communication…

- ***Periodic Review***
  - This lets us use new info (e.g. market and route surveillance, deviations, process experience, weather-related events, etc.) to increase knowledge about weather-related hazards, and to improve the **Risk Assessment.**

- ***Risk Communication***
  - Necessary and critical - helps promote a culture of weather risk awareness.

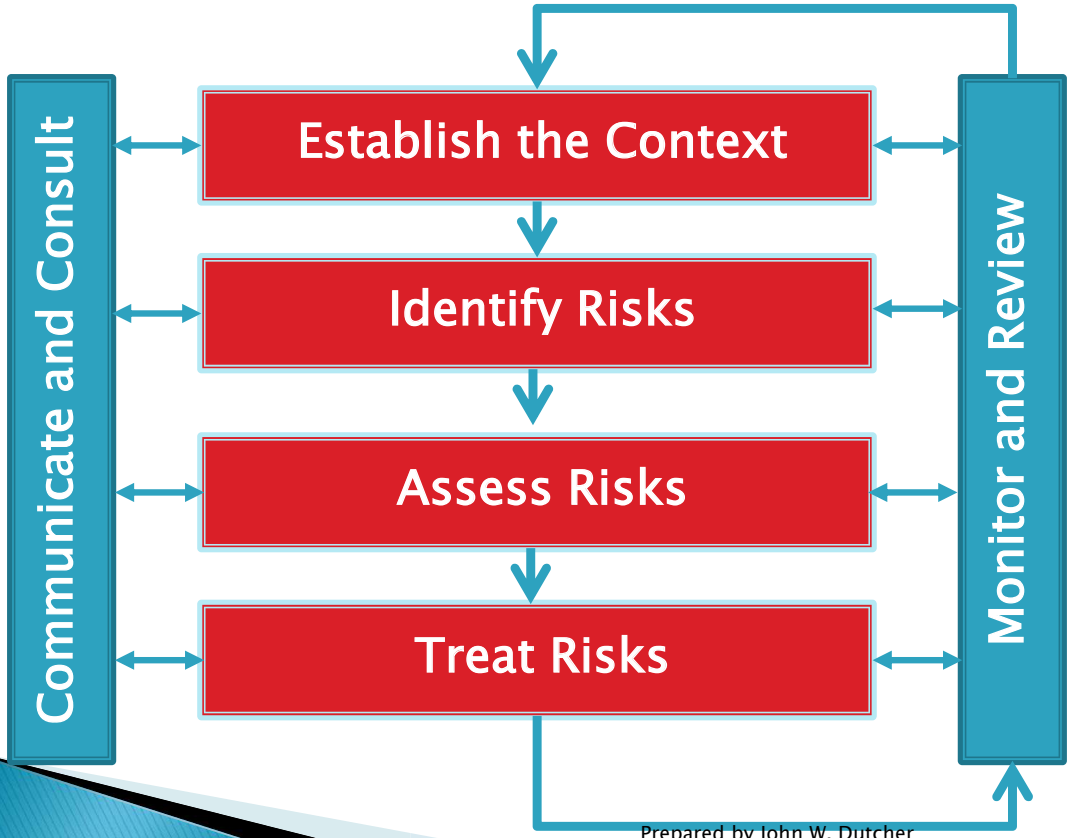
Prepared by John W. Dutcher (2021)

MONITOR & REVIEW

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)

Weather Risk Management Process



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MONITORING AND REVIEW

- Monitoring and review is an integral part of the risk management system, it also supports continual improvement.
- Risk is dynamic and so are companies and organisations / systems.
  - Few risks remain static.
- Changing circumstances can affect the need for treatment of risks, alter priorities, or mean that selected treatment methods are no longer effective.
- There must be monitoring of risks, treatment plans and strategies, and the management systems set up to control implementation.

Prepared by John W. Dutcher (2021)

MONITORING AND REVIEW

- Monitor over time to ensure:
  - The controls are effective.
  - The controls remain in place.
  - Changes that require further risk controls are identified and implemented
  - Ineffective risk controls are identified and corrected, improved.
  - Personnel, mission, or equipment changes are subjected to the process.
  - Learn from the experience
  - Experience is transferable

MONITORING AND REVIEW

- Progress should be monitored by the identification and tracking of Key Performance Indicators (KPIs), milestones, etc when an WRM project plan is developed.

- Performance indicators in measurable units should also be established to clearly demonstrate whether the intervention is meeting its aims and objectives and how efficiently it is achieving outcomes.

Prepared by John W. Dutcher (2021)

MONITORING AND REVIEW

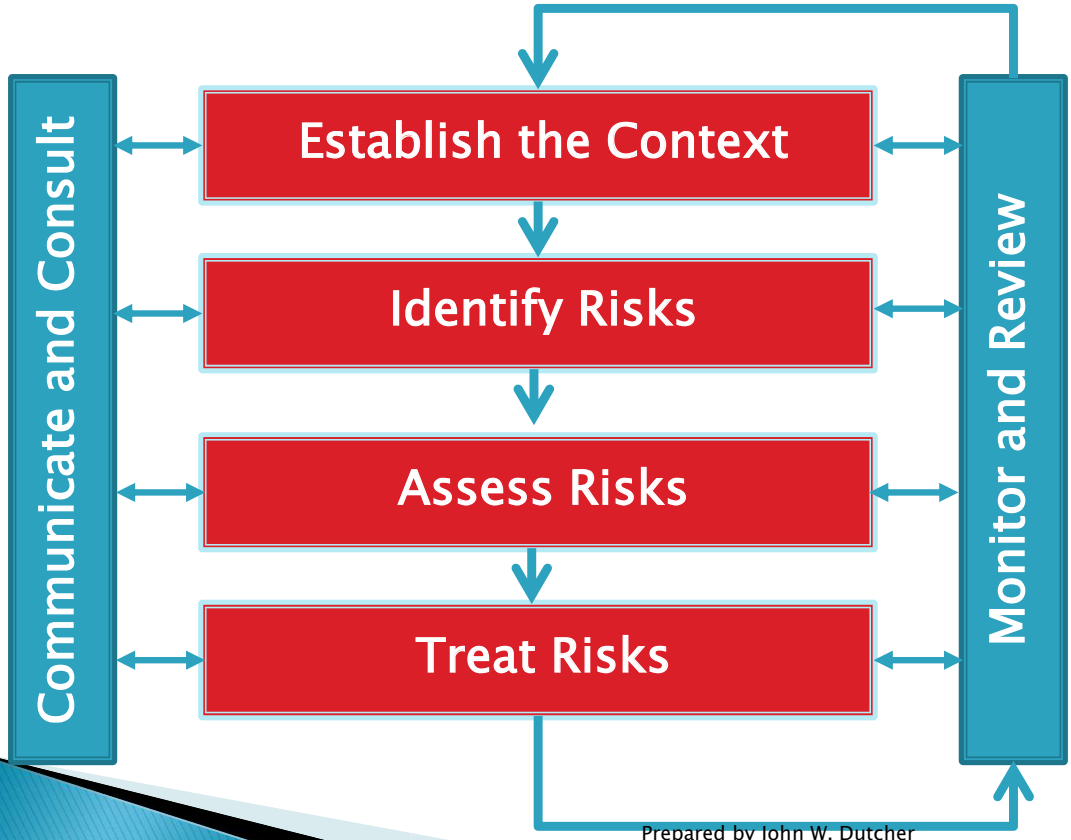
- Set up a systematic review process
  - What effect has the control had on your company
  - Are newly discovered hazards identified, assessed, and controlled?
  - What will you use to monitor trends
  - Be prepared to discuss "Spikes"

COMMUNICATE & CONSULT

WEATHER RISK MANAGEMENT PROCESS

Prepared by John W. Dutcher (2021)

Weather Risk Management Process



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COMMUNICATE & CONSULT

- Communication and consultation are intrinsic to the process of risk management and should be considered at each step.
- Because of the types of risk dealt with in the WRM process there should be a process of consultation and dialogue.
- The WRM project is more likely to be successful when stakeholders understand each other's perspectives and are actively involved in decision-making.

Prepared by John W. Dutcher (2021)

COMMUNICATE & CONSULT

- Effective communication and consultation will:
  - Improve people's understanding of risks and the weather risk management process;
  - Ensure that the varied views of stakeholders are considered; and
  - Ensure that all participants are aware of their roles and responsibilities.

QUESTIONS?