

維修與飛航事故調查 (HFACS-ME)

飛航安全調查委員會

李寶康 / 飛航安全官





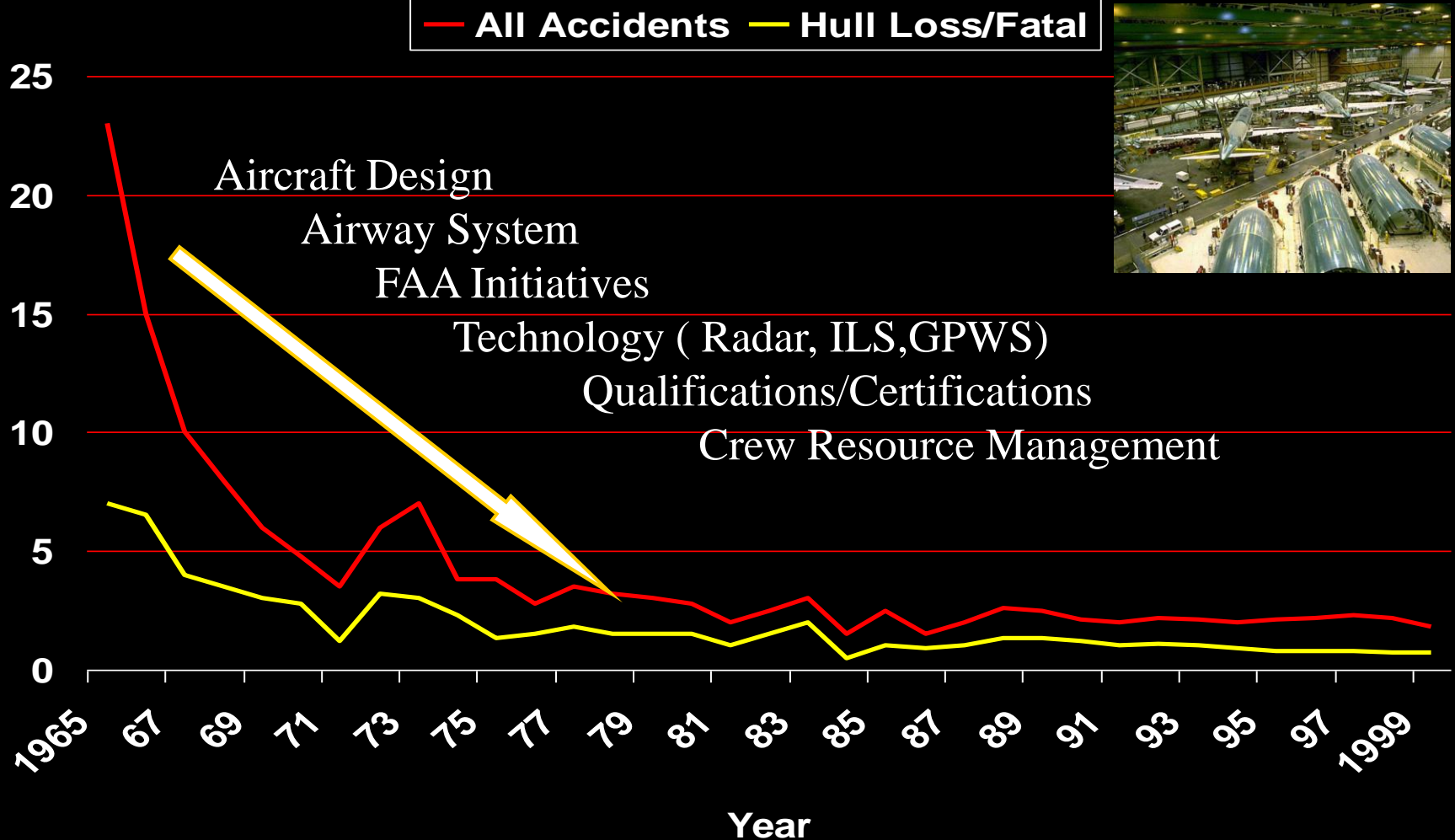
Introduction to Maintenance Error Analysis



Naval Safety Center
School Of Aviation Safety



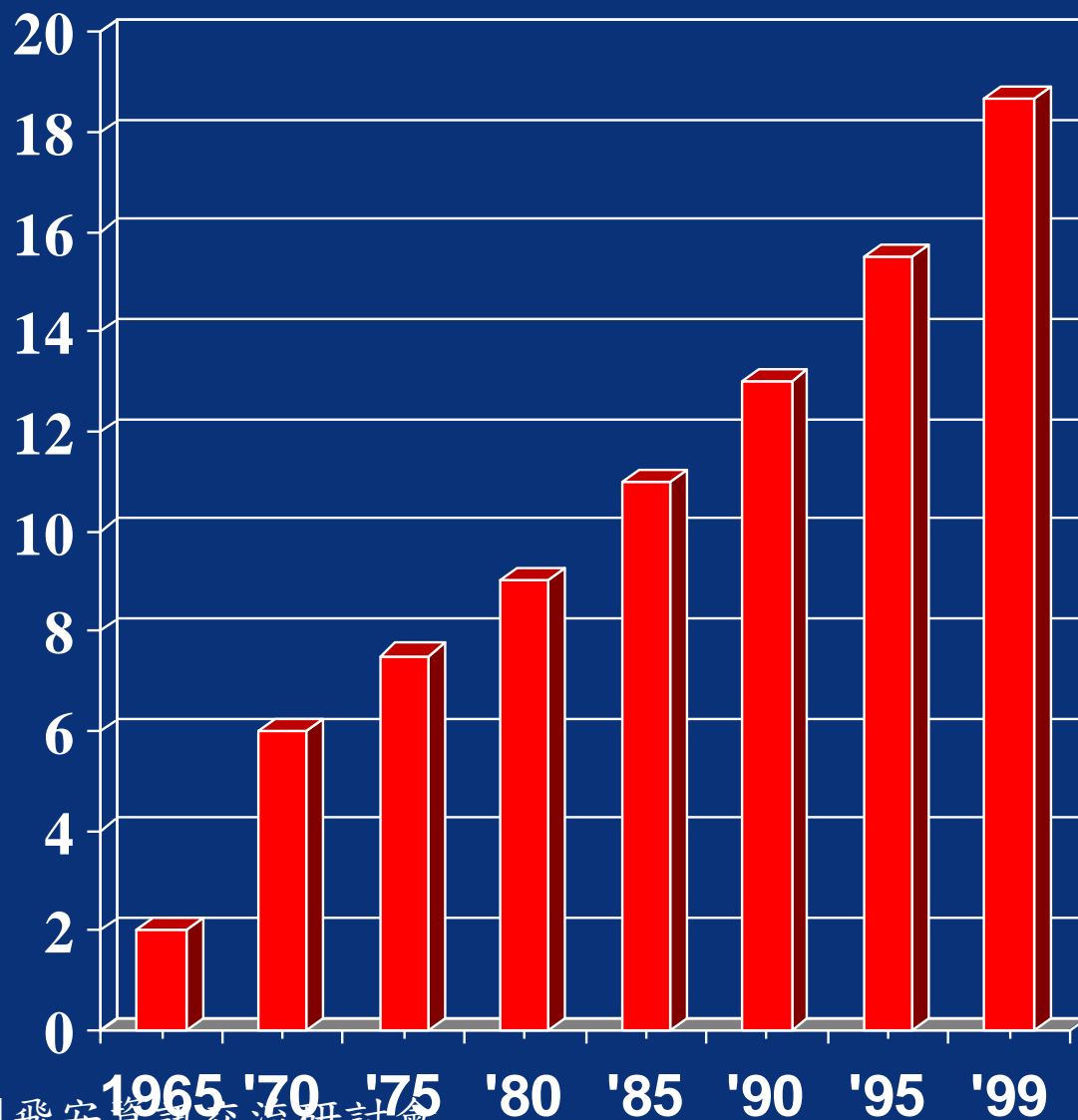
Worldwide Commercial Jet Accident



Accident Rate (accidents per million departures)

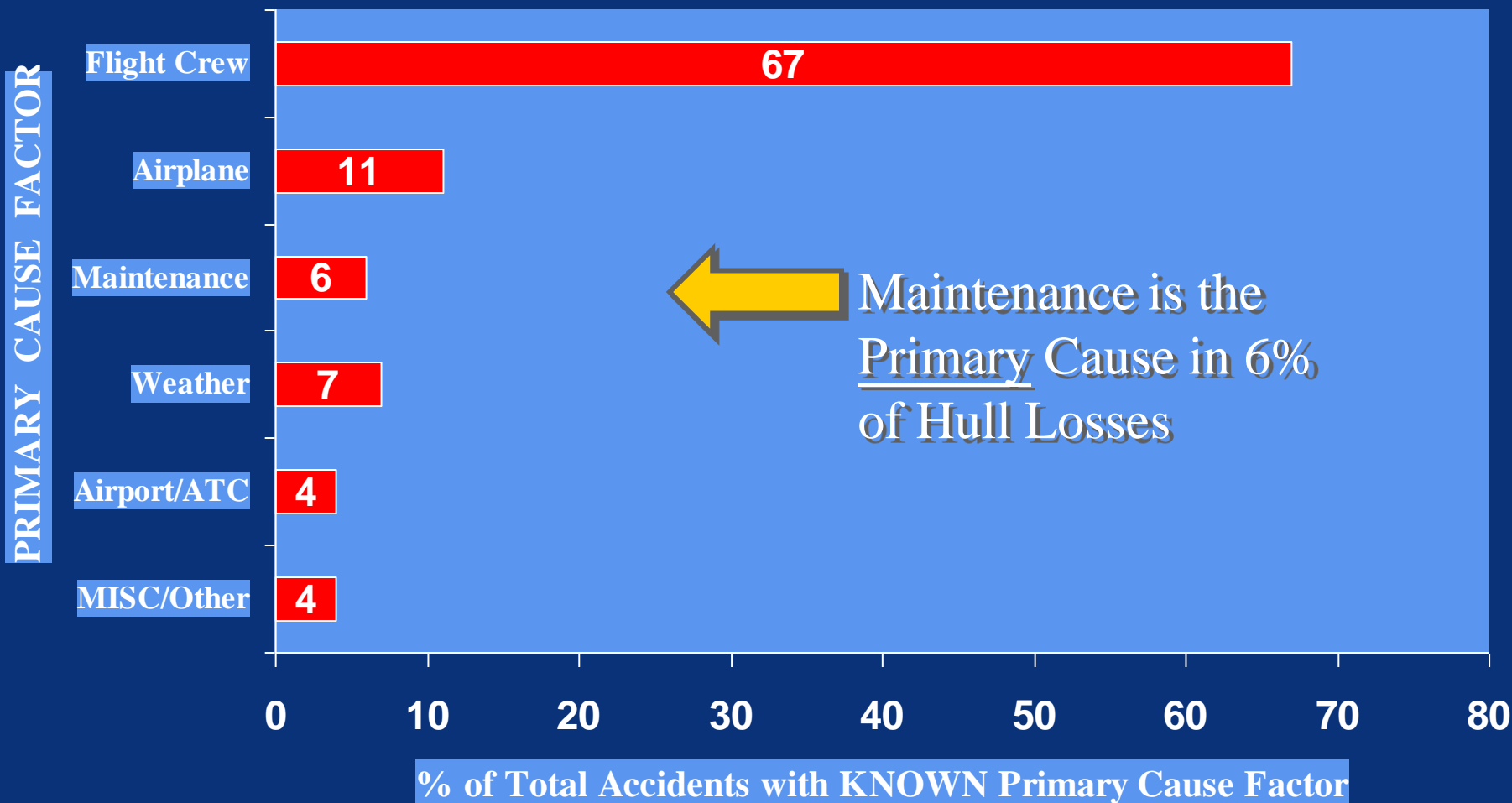


Worldwide Departures 1965-1999



■ Annual Departures (millions)

Primary Cause of Hull Loss Accidents Worldwide Commercial Jet Fleet (1990-1999)



(Boeing, 2000)

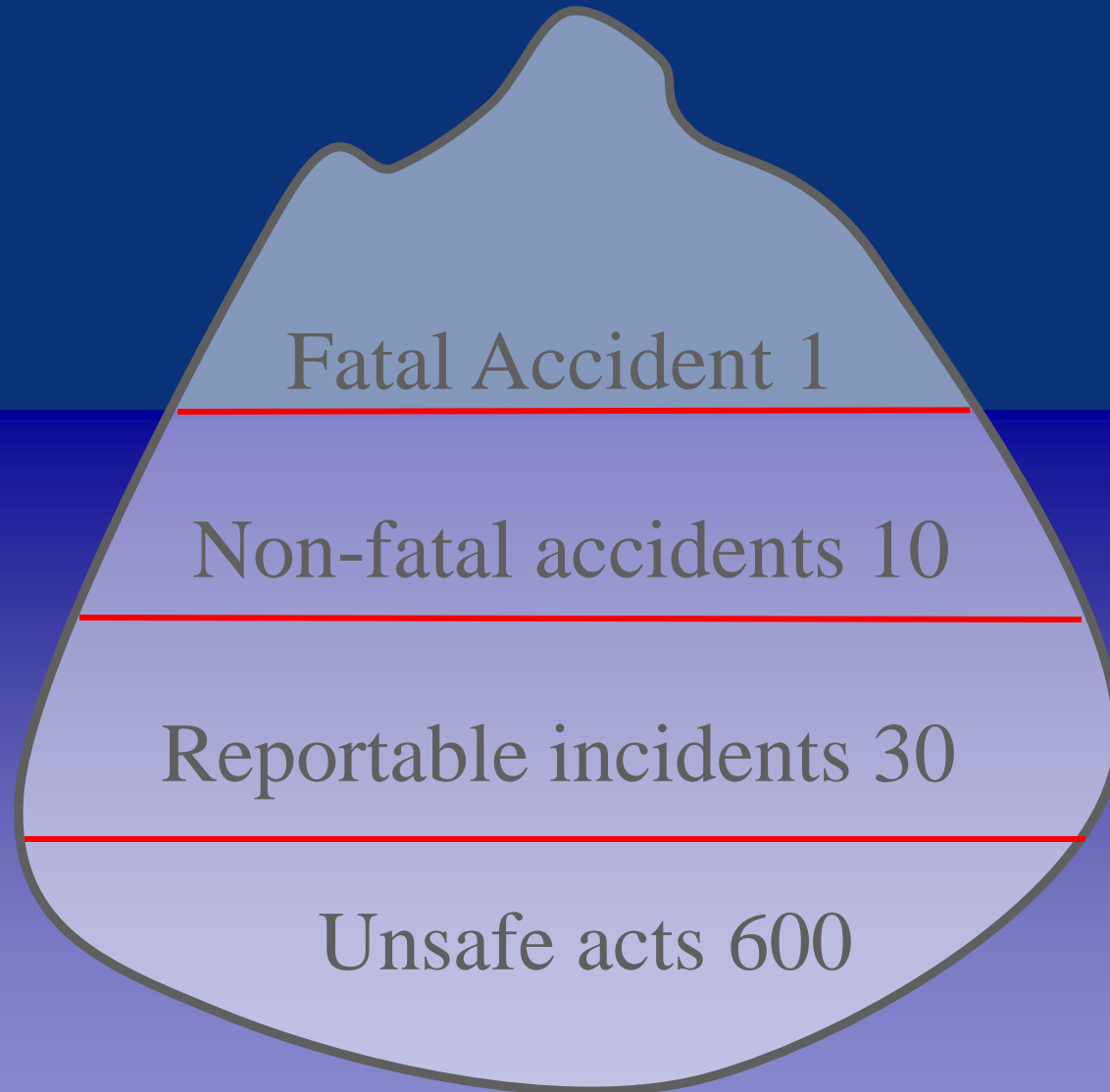
How Significant are Maintenance Factors?



Studies found that:

- Maintenance contributed to 15% of commercial jet accidents (Boeing, 1995)
- Maintenance was the 2nd greatest contributor to fatalities, following CFIT (CAA, 1992)

The Heinrich Ratio



Additional Maintenance/Ramp Error Data

20-30% of engine in-flight shutdowns and 50% of engine-related flight delays/cancellations are caused by maintenance error (Boeing, 1997)



48,800 non-airworthy aircraft are dispatched per year as a result of maintenance error (Marx, 1998)



Ramp accidents cost \$2-2.5 Billion annually (Ramp Safety, Vol. 11:3)



Maintenance Accident Costs

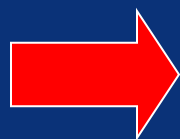
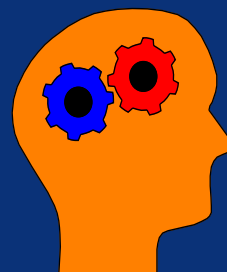
- Avg. cost of an in-flight engine shutdown is \$500,000
- Avg. cost of a flight cancellation is \$50,000
- Avg. cost of a return to gate is \$15,000
- Avg. ground damage incident costs \$70,000
- One airline estimates \$75-\$100 million/year is lost
- Airline Transport Association estimates that ground damage costs \$850 million/yr

(Source: hfskyway.faa.gov)

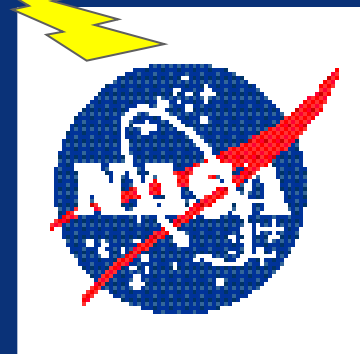


Paradigm Shift: Aloha Airlines, 1988

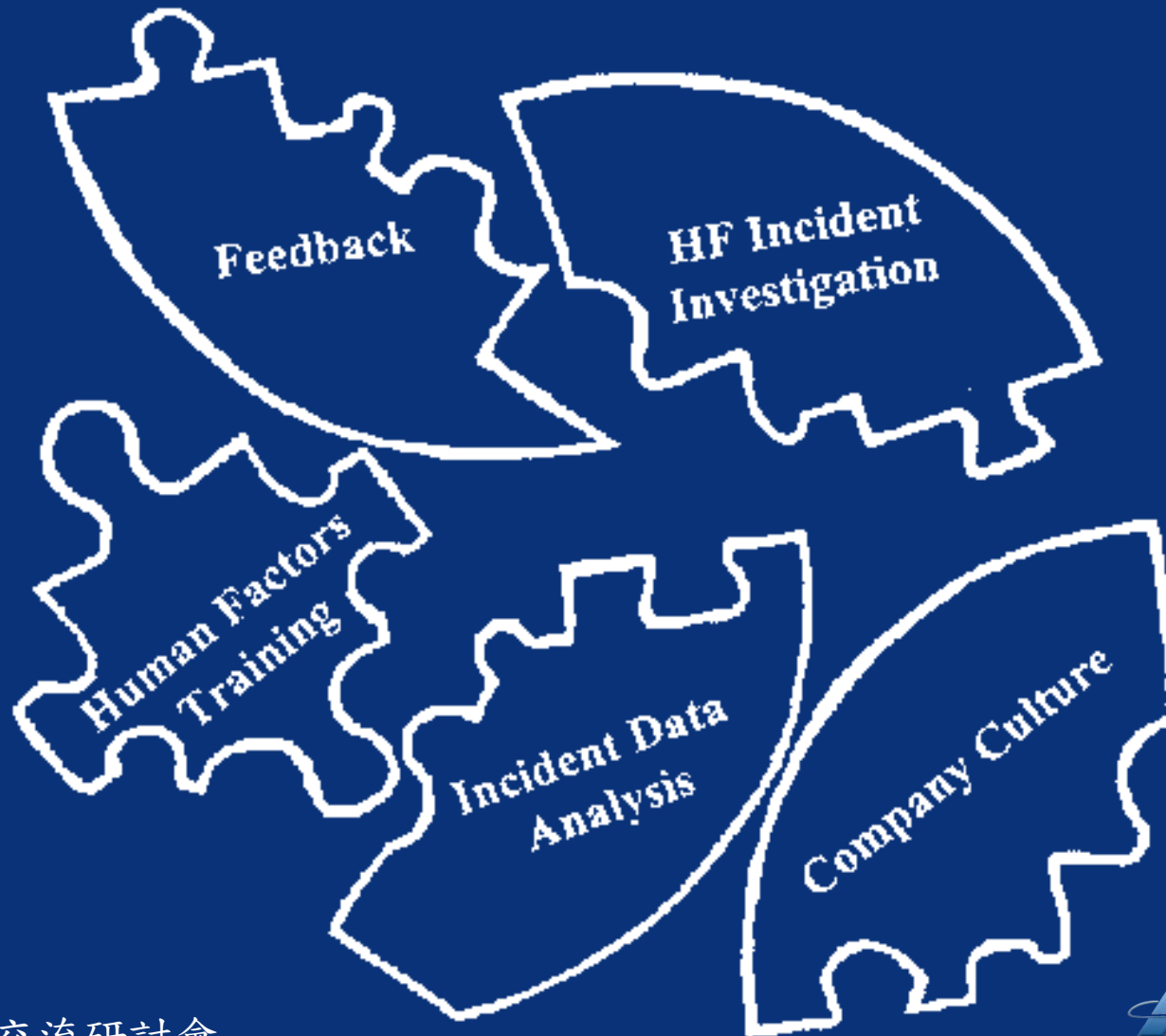
Watershed Event



Brainstorming



Maintenance Resource Management Programs





- Error, Incident, Hazard, & Accident Investigation/Reporting
- Determine Cause Factors (& Targets for Subsequent Intervention)
- Provide Information for Suggesting Intervention Development



- Identify Causal Factor Patterns/Trends
- Assess Hazards/Risks to Prioritize Potential Targets for Intervention
- Provide Means to Forecast Potential Impact of Identified Interventions (ROI)



- Establish Metrics for Evaluating Intervention Effectiveness (ROI)
- Provide Lessons Learned for Specific Operations/Locations
- Permit Team/Individual Participation in the Development of Interventions



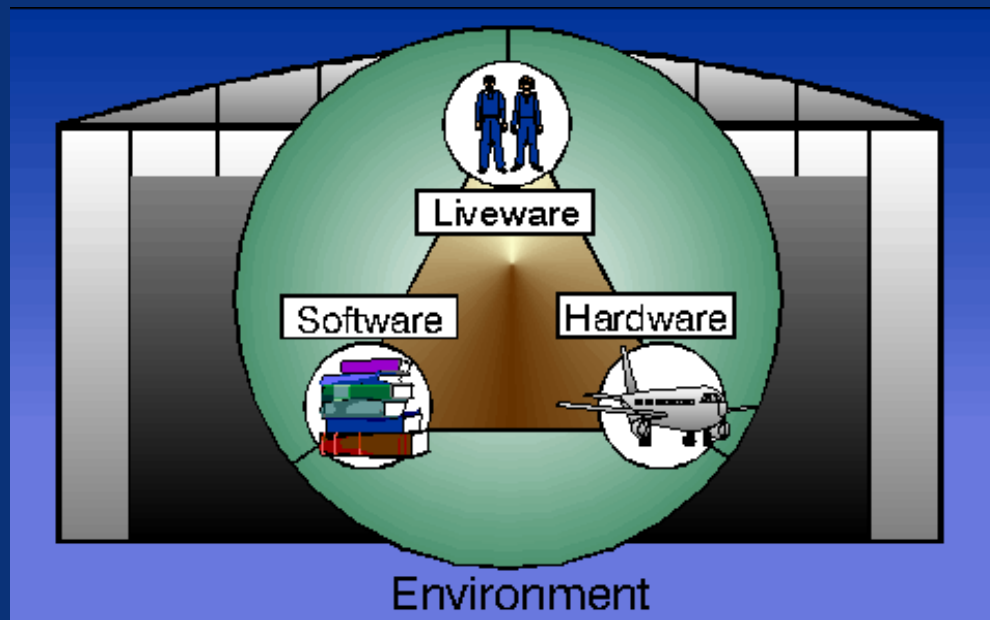
- Reporting Errors, Incidents, Hazards, & Accidents
- Active Participation in Intervention Development
- Proactive Identification of Hazards/Errors
- Top Management Support & Individual Buy-In



- Individual Worker - Awareness & Skill Development (Performance Optimization, Personal Safety, Team Synergy, & Proactive Improvement)
- Line Supervisor - Awareness, Skill (listed above), Implementation, & Investigation/Reporting
- Upper Management - Awareness, Overview of Skills, Investigation/Reporting, Implementation, & Metrics
- Safety/QA - Awareness, Skill Development (listed above), Implementation, Investigation/Reporting, & Metrics

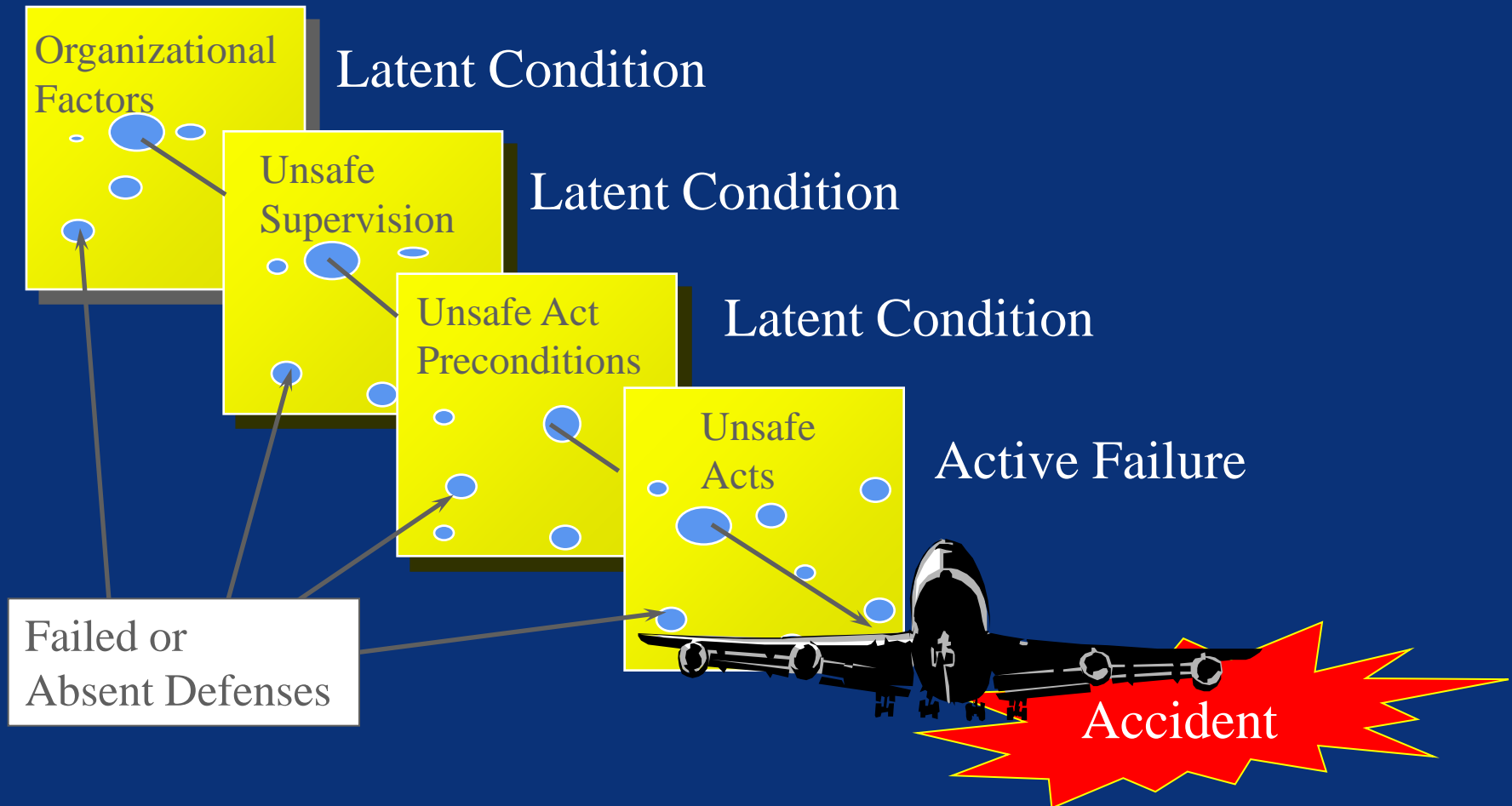


“Edward’s Shell Model”

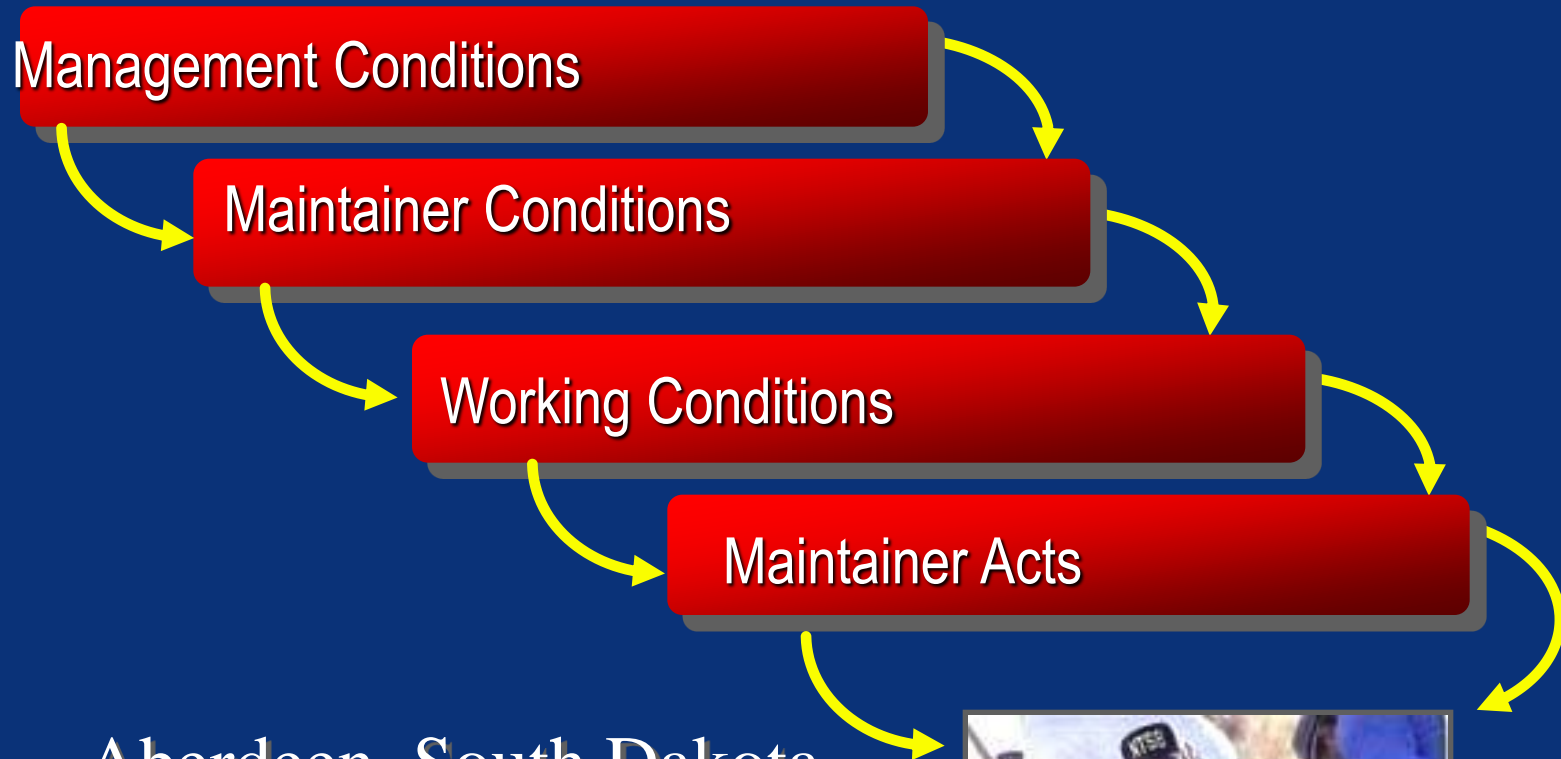


“Heinrich’s Domino Theory”

Reason's "Swiss Cheese" Model



HFACS- Maintenance Extension



Aberdeen, South Dakota
(Payne Stewart accident)
October 25, 1999



HFACS-ME in Commercial Aviation

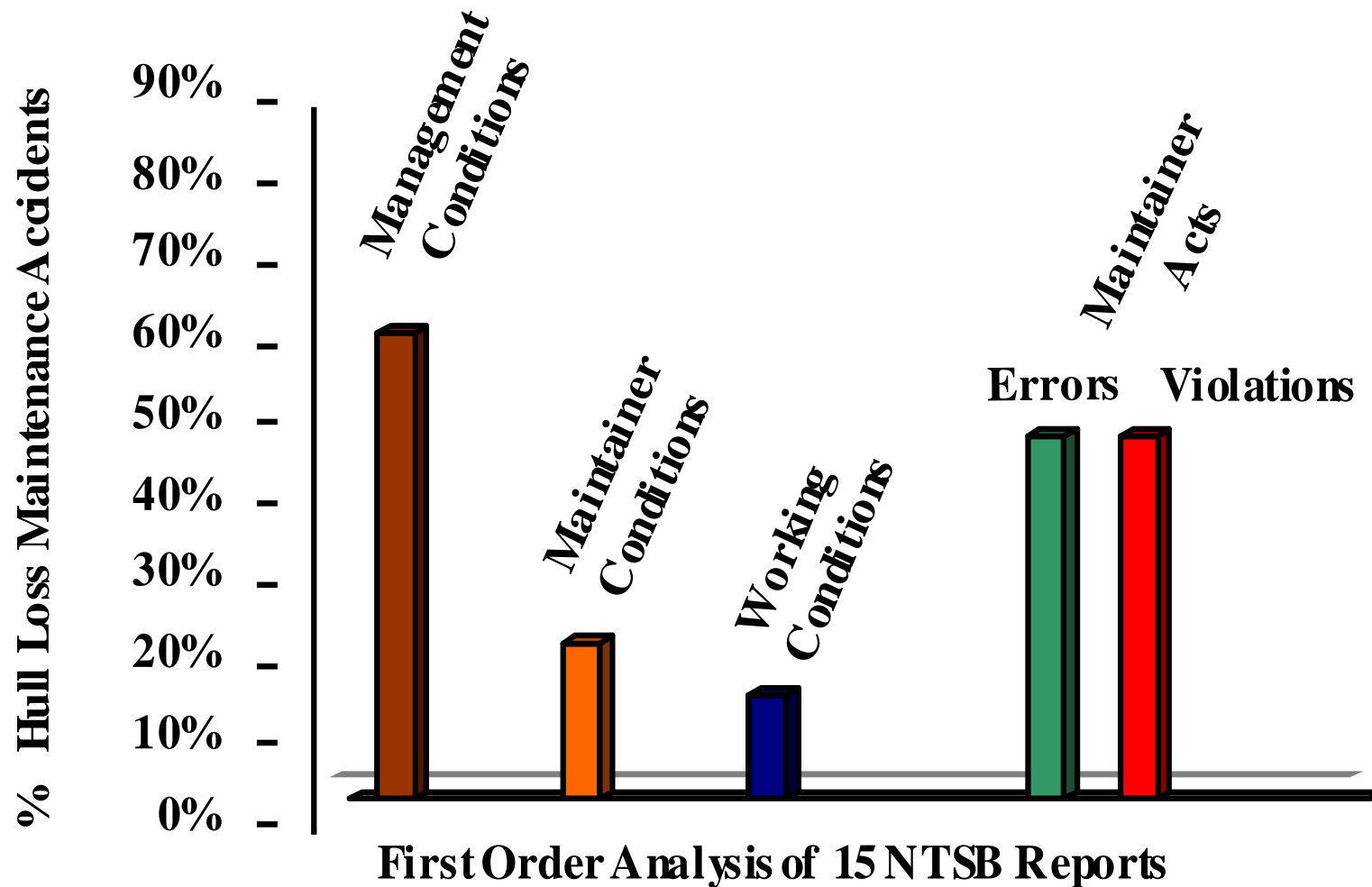
The FAA's Office of Aviation Medicine requested that the US Navy's School of Aviation Safety apply HFACS-ME to commercial airline accidents

15 NTSB Maintenance related accident reports were analyzed from provided sets

HFACS-ME was successfully used to code existing NTSB reports



HFACS-ME Results of NTSB Reports



*NOTE: Similar proportions were found in US Navy accidents!

HFACS-ME Summary

- (1) HFACS-ME is effective in classifying maintenance errors.
- (2) HFACS-ME may be utilized on both major and minor accidents to fully capture maintenance errors.
- (3) HFACS-ME enables organizations to develop successful intervention strategies.



HFACS-ME

**Human Factor Analysis and Classification System –
Maintenance Extension**



維修相關調查案例介紹



案例一

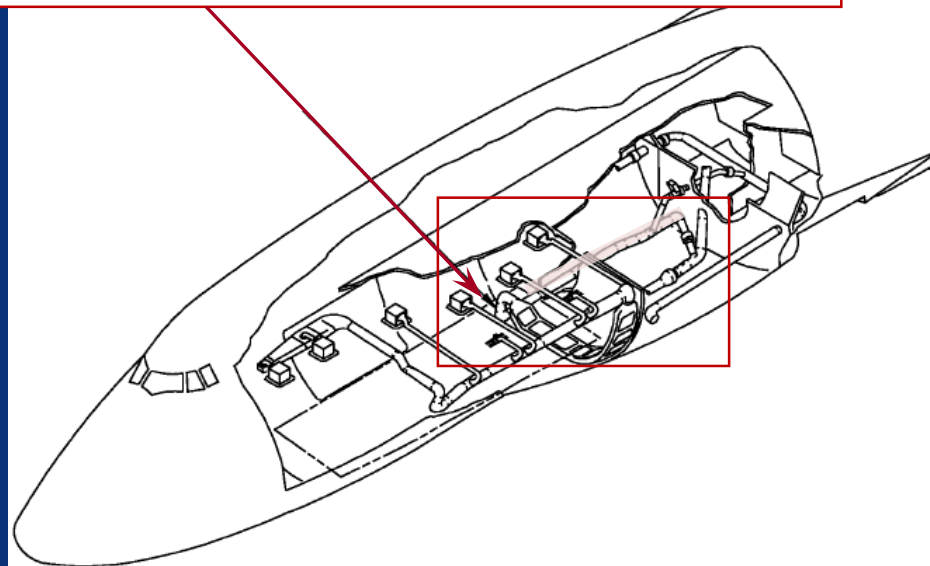
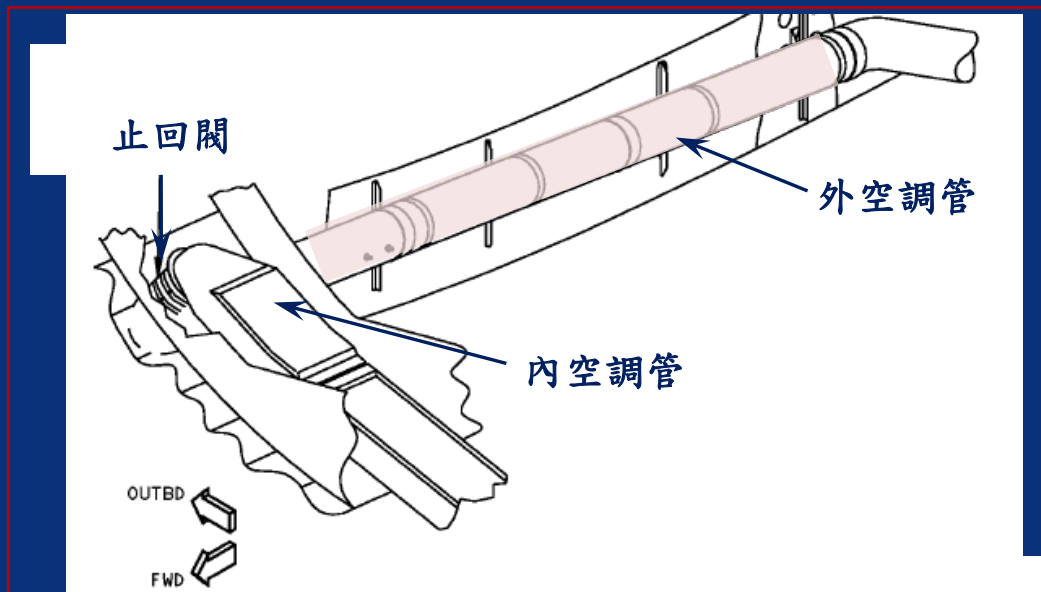
- 該機起飛後到達30,000呎巡航時，Upper EICAS DU出現艙壓異常警告，檢查外流閥位於關閉位置，檢查艙壓高度在10,400呎且繼續上升，艙壓高度上升速率約在400呎/分至500呎/分之間，正駕駛員宣告緊急狀況，戴上氧氣面罩，執行緊急下降程序，並通知航管導引降落，人機均安。



事故後檢查

- 檢查空調系統管路時發現，供應至前貨艙之3號空調機管路自止回閥與機身加壓艙耦合處脫落。

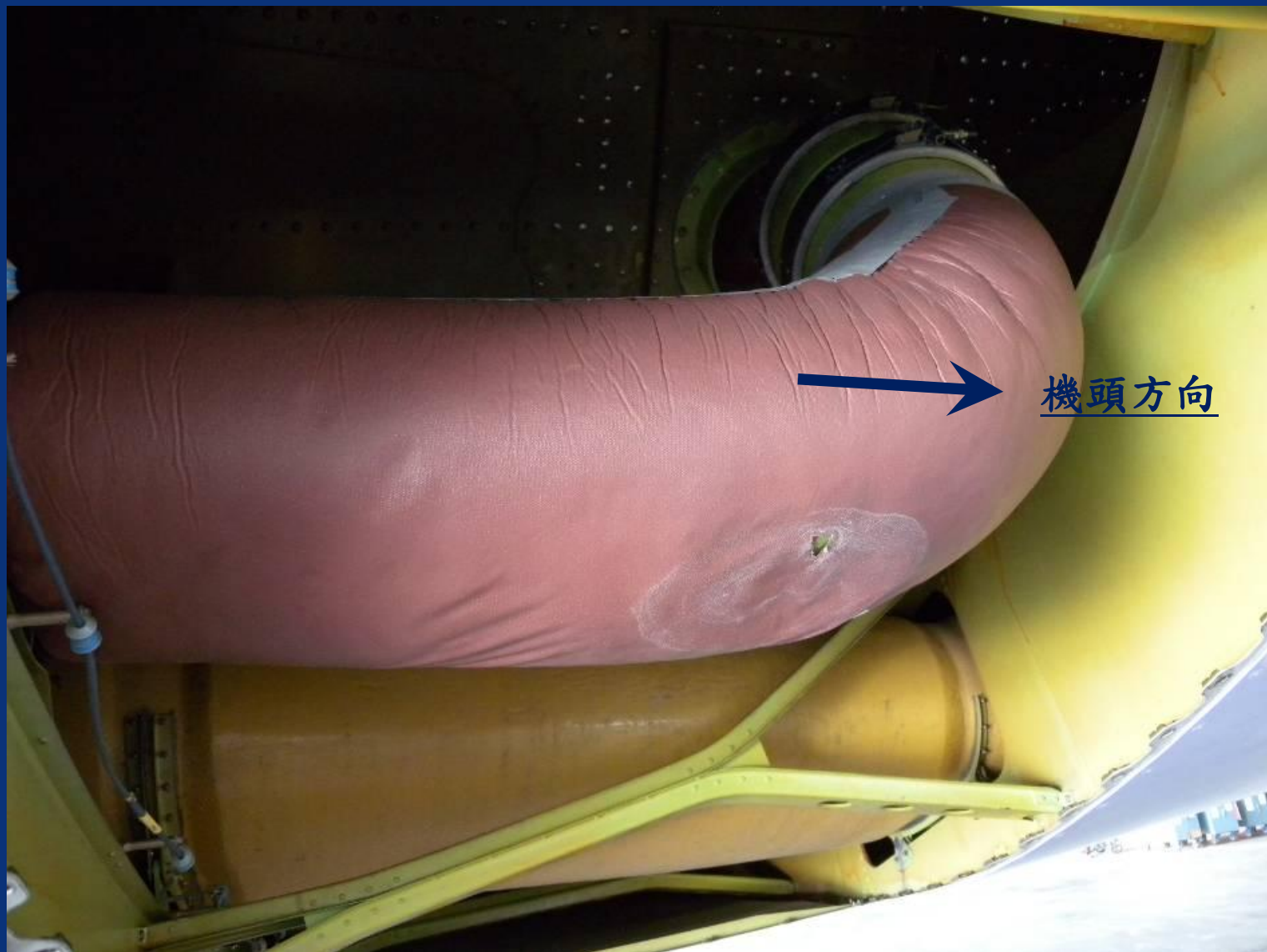
脫落空調管位置



空調管脫落情形(一)



空調管脫落情形(二)



維修紀錄

- 依據該型機航空器維護計畫（Aircraft Maintenance Program, 以下簡稱AMP），3號空調系統脫落部位止回閥之狀況檢查，為每4C定檢時執行，檢查時須將止回閥拆下，檢查後再予裝復，上次執行該項檢查時間為民國98年8月24日。

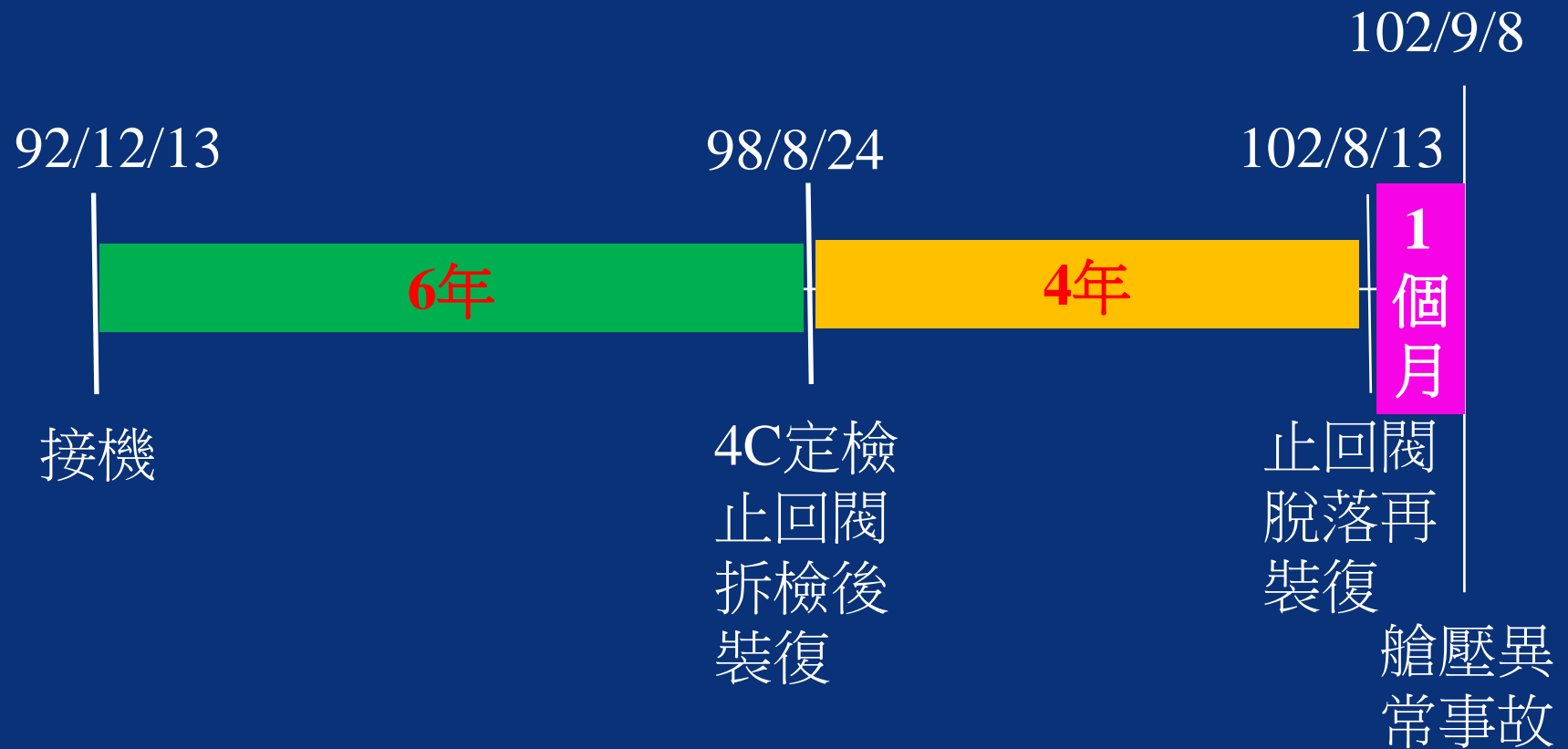


維修紀錄

■ 維護紀錄顯示

- 該機於民國102年8月12日駕駛員報告「STS MSG ZONE TEMP」，維修員據報檢查CMC發現「FWD CGO DUCT TEMP SENSOR/WIRING FAIL(T1657)」訊息。
- 該機於民國102年8月13日，於執行管路溫度感測器檢查更換時，發現空調管塌陷、感溫器損壞。

止回閥連續脫落事件簿



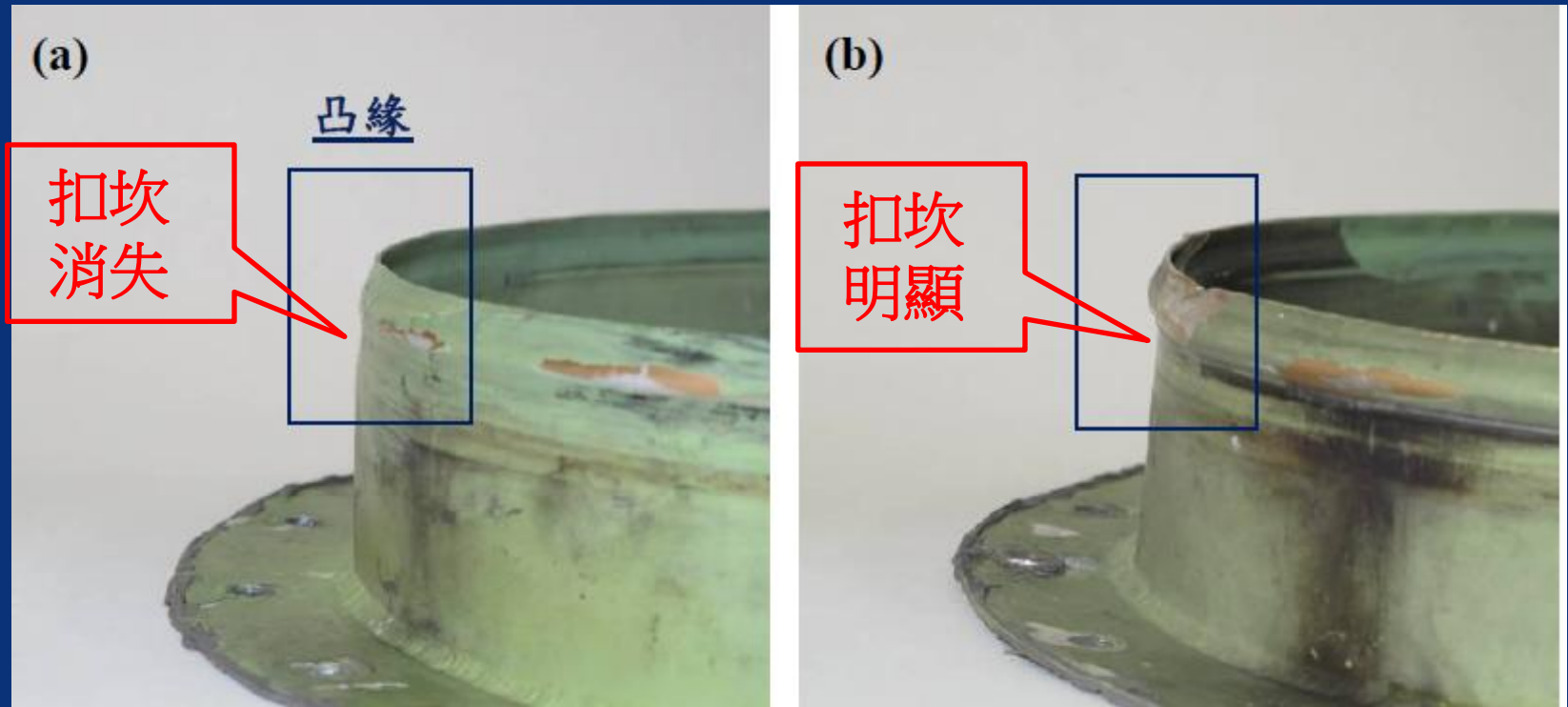
現場觀察

- 變形之凸緣
- 管夾安裝之上磅程序
- 管夾扣件之構成
- 飛機維修手冊

變形之凸緣



變形之凸緣



飛機維修手冊

CHAPTER

20

**STANDARD
PRACTICES**



飛機維修手冊



747-400

AIRCRAFT MAINTENANCE MANUAL

BOEING PART NUMBER	DASH NUMBER ()	TORQUE (INCH- POUNDS)	TORQUE (NEWTON- METERS)	BOEING PART NUMBER	DASH NUMBER ()	TORQUE (INCH- POUNDS)	TORQUE (NEWTON- METERS)
BACC10AC	150-200	40-50	4.52-5.65	BACC10KH	200-275	45	5.08
	225-300	60-70	6.78-7.91		300-475	55	6.21
	315-550	120-140	14.01-15.81		500-550	60	6.78
BACC10AUU()	250-275	70	7.91		600-650	65	7.34
	300-500	100	11.30		700	70	7.91
	550-600			BACC10LE()	500-600	55	6.21
BACC10BR8()	100-900	100	11.30		650-900	65	7.34
BACC10CT2()	100-600			NUCO (U430453)	125	55-65	6.21-7.34
BACC10DP()A	150-250						

COUPLING CLAMPS, V-BAND, AND CHANNEL-BAND 1

- 1 THE RECOMMENDED TIGHTENING PROCEDURE IS AS FOLLOWS:
1. APPLY THE INSTALLATION TORQUE AS GIVEN IN THE TABLE.
 2. HIT THE ENTIRE CIRCUMFERENCE OF THE CLAMP LIGHTLY WITH A WOOD, LEATHER, OR SOFT PLASTIC Mallet.
 3. DO STEPS 1 AND 2 UNTIL THE TORQUE WILL STAY CONSTANT.

BACC10HX()	475-600	55	6.21
	650-900	65	7.34
	100-300	10	1.13
	325-500	15	1.69
	550-800	20	2.26

COUPLING CLAMPS, V-BAND, AND CHANNEL-BAND 1

- 1 THE RECOMMENDED TIGHTENING PROCEDURE IS AS FOLLOWS:
1. APPLY THE INSTALLATION TORQUE AS GIVEN IN THE TABLE.
 2. HIT THE ENTIRE CIRCUMFERENCE OF THE CLAMP LIGHTLY WITH A WOOD, LEATHER, OR SOFT PLASTIC Mallet.
 3. DO STEPS 1 AND 2 UNTIL THE TORQUE WILL STAY CONSTANT.

Standard Torque Values for Clamps
Figure 209 (Sheet 1 of 2)/20-51-01-990-809

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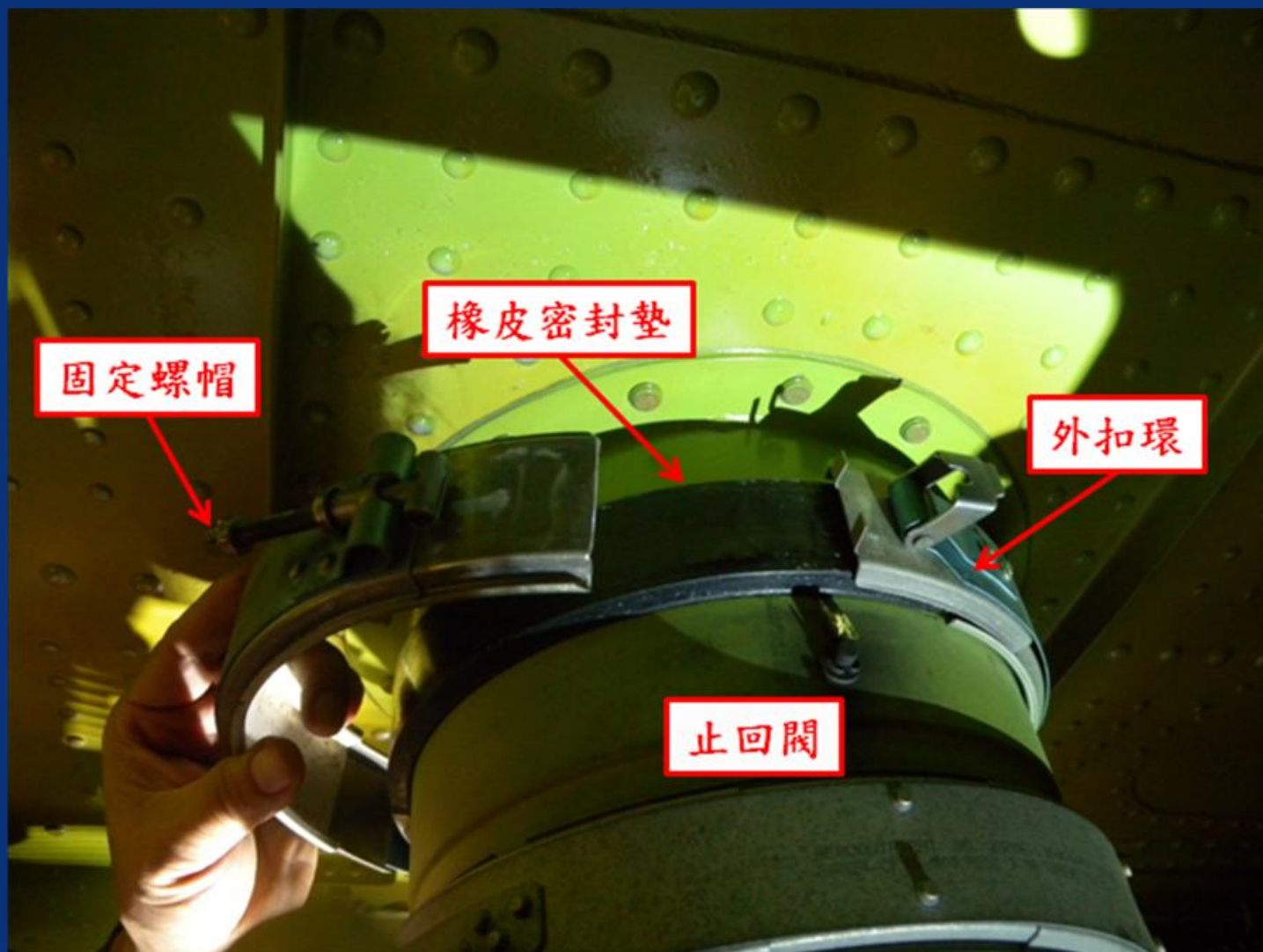
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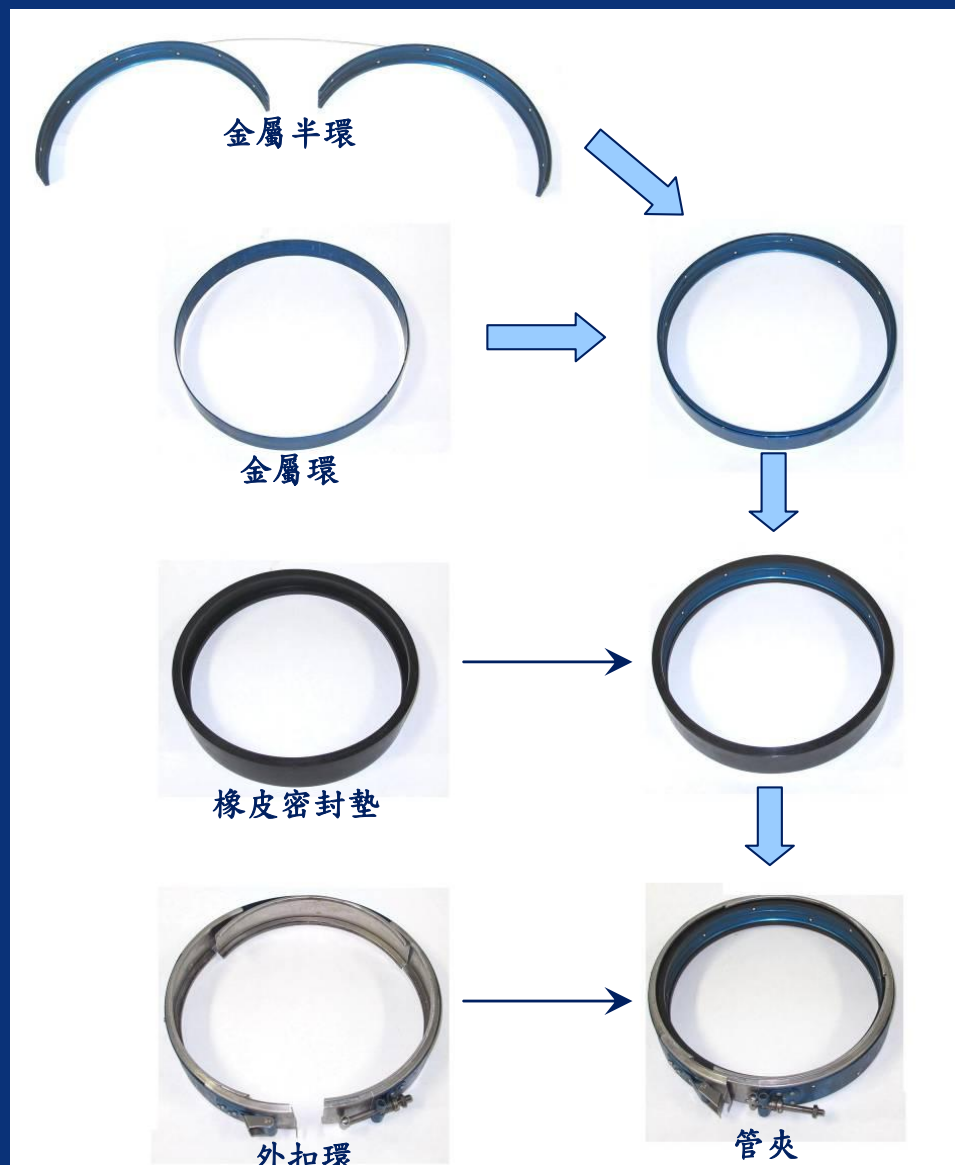
管夾扣件之構成



管夾扣件之構成



管夾扣件之構成



飛機維修手冊

- THE RECOMMENDED TIGHTENING PROCEDURE IS AS FOLLOWS: (中譯：建議依下列步驟上磅。)
 - 1. APPLY THE INSTALLATION TORQUE AS GIVEN IN THE TABLE.(中譯：依前表相應磅數上磅。)
 - HIT THE ENTIRE CIRCUMFERENCE OF THE CLAMP **LIGHTLY** WITH A WOOD, LEATHER, OR SOFT PLASTIC Mallet.(中譯：以木質、皮革或軟質橡膠槌輕力敲擊環夾圈圍。)
 - **DO STEPS 1 AND 2 UNTIL THE TORQUE WILL STAY CONSTANT.**(中譯：施行前項1,2,步驟至磅數穩定為止。)



HFACS-ME

Human Factor Analysis and Classification System –
Maintenance Extension

案例一

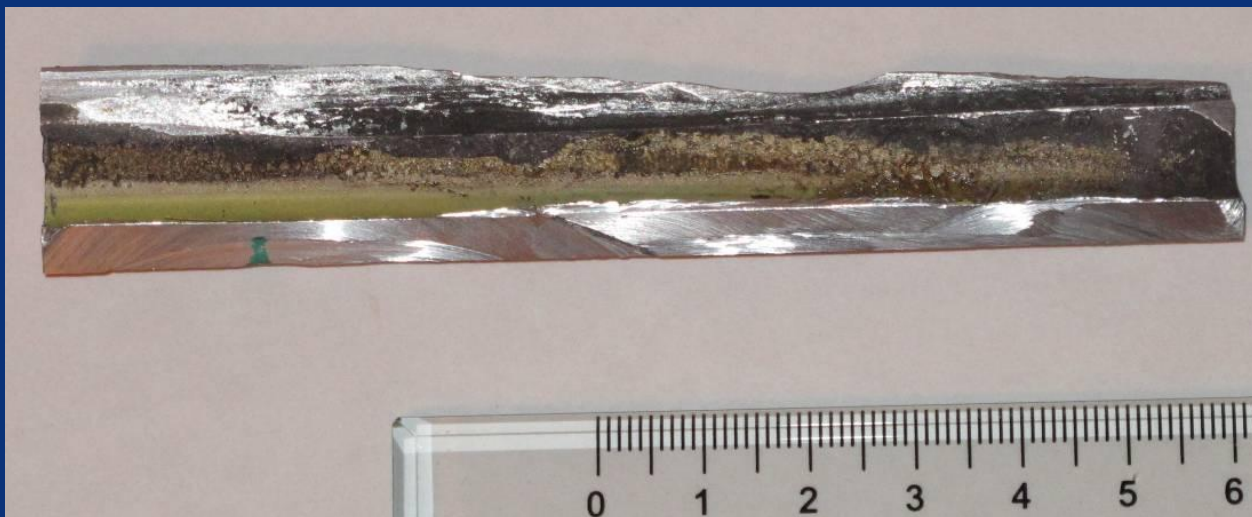


案例二

- ❖ 該機從松山機場向東起飛，預計經鶯歌到桃園縣復興鄉山區實施高高度飛行訓練，起飛至航線三邊時（民權東路上空）左貨艙門掉落台北市民生國中圍牆。

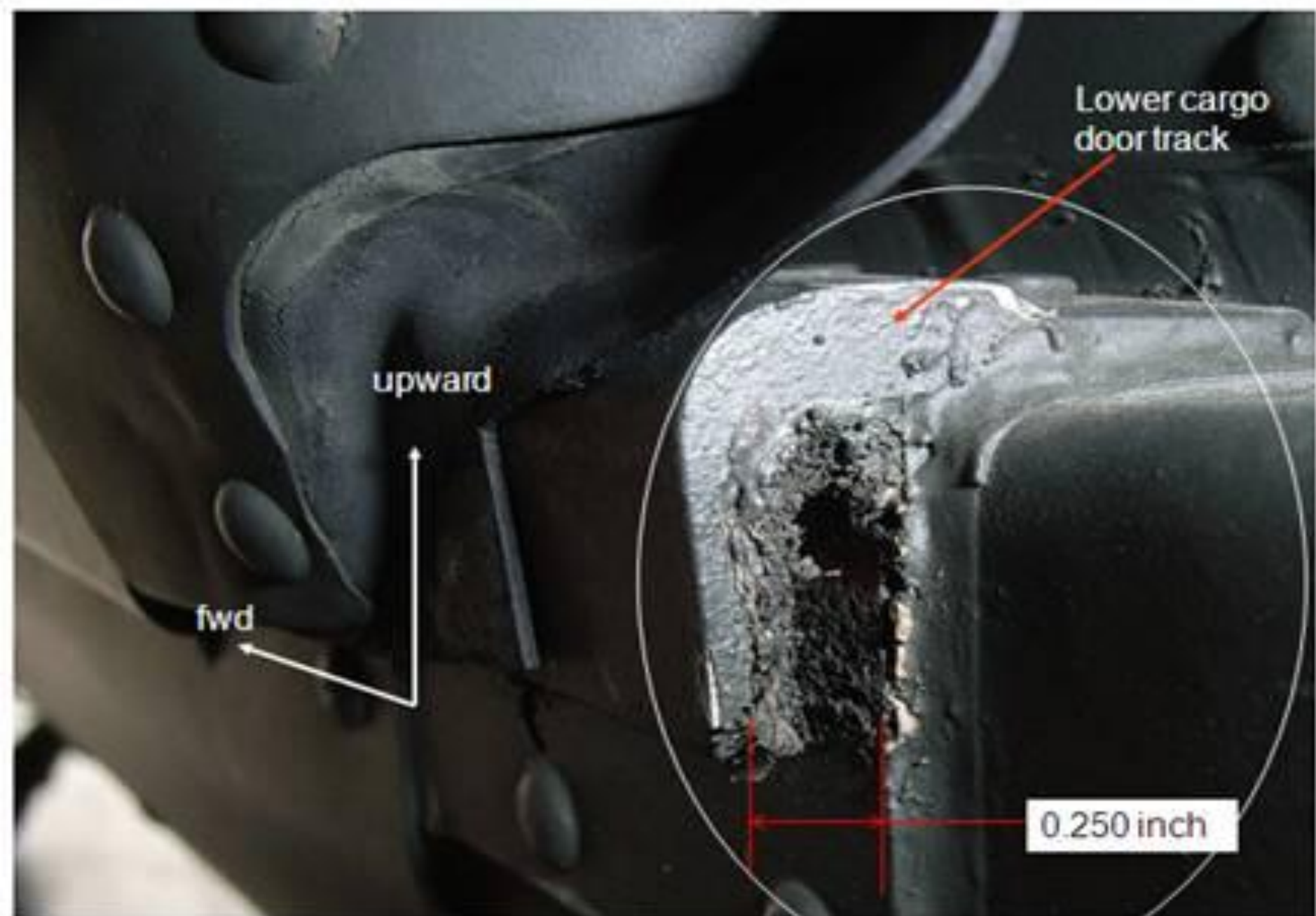




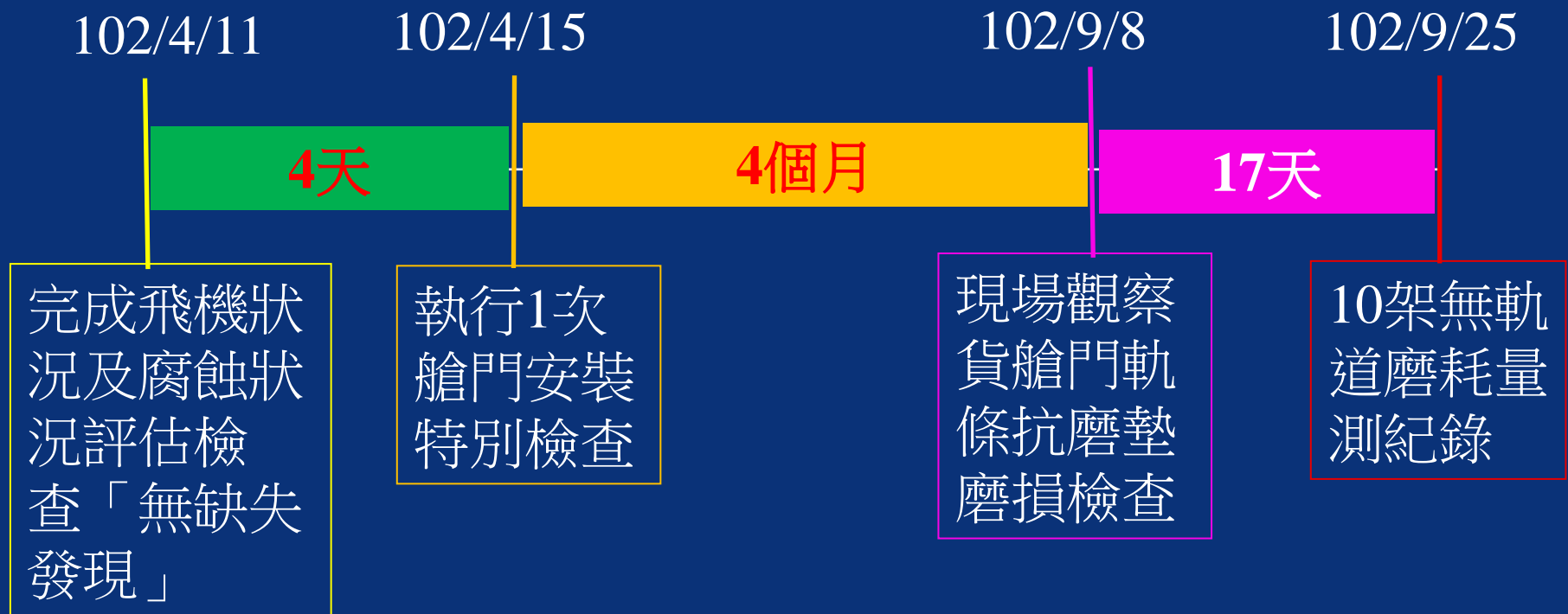








艙門脫落事件簿



調查發現

- 機工長於起飛前執行後艙確認未落實。
- 商維公司執行艙門檢查未落實。



HFACS-ME

Human Factor Analysis and Classification System –
Maintenance Extension

案例二



省思

- 飛機製造廠出版之手冊未必完整
- 組織對故障處理審慎之態度
- 各管理階層對組件送修程序之重視
- 各專業工廠對其修護能量之瞭解
- 維修員管夾締緊上磅程序之訓練



報告完畢