Taiwan TTSB 國家運輸安全調查委員會 Transportation Safety Board

The Development of the Integrated Human Fatigue Investigation Methodology and its Application

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Outline

① Fatigue Causes

② Introduction of the TTSB Fatigue Investigation Guide

③ Integrated Fatigue Risk Factors Diagram

④ Fatigue Issues Related to GE222 CFIT Accident

⑤ Conclusions

① Fatigue Causes

ICAO Fatigue Definition

Fatigue in aviation has been defined by ICAO (Doc 9966, 2011):

Symptoms — *A physiological state of reduced mental or physical performance capability*

Causes — *resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/ or physical activity)*

Consequences — *that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties.*

Fatigue Investigation Guides

① Appendix I. Evaluating the Contribution of Fatigue to Safety Events, Second edition, ICAO Doc 9966 (2016)

② Guide to Investigating Sleep-Related Fatigue, Second Edition, TSB Canada (2014)

- ✓ Sleep & fatigue knowledge
- ✓ Method for investigating fatigue
- ✓ Fatigue data collection and analysis tools

③ Methodology For Investigating Operator Fatigue in a transportation accident, NTSB (2006)

④ Fatigue CheckCard for Mishap Investigation, AFRL (2004)

⑤ A Guide for Investigation for Fatigue, TSB Canada (2002)

⑥ Fatigue Investigation Checklist, ATSB (2001)

Fatigue Causes	ICAO	TSB, Canada	TTSB
	Sleep-related fatigue Physical fatigue Mental fatigue	Sleep-related fatigue	Sleep-related fatigue Physical fatigue Mental fatigue
Acute sleep deprivation	O	O	O
Chronic sleep deprivation	O	O	O
Continuous wakefulness	O	O	O
Circadian rhythm effects	O	O	O
Sleep disorder	O	O	O
Workload	O	X	O
Psychological conditions, illness or medicine effects	X	O	O

② Introduction of the TTSB Fatigue Investigation Guide

ICAO Doc 9966 indicates that:

Fatigue is a major human factors hazard because it affects most aspects of a crewmember's ability to do their job.

How to conclude fatigue was a probable cause, risk factor, or not an issue during the investigation?

Previous investigation experience

Learning from training courses related to fatigue investigation, management or human factors

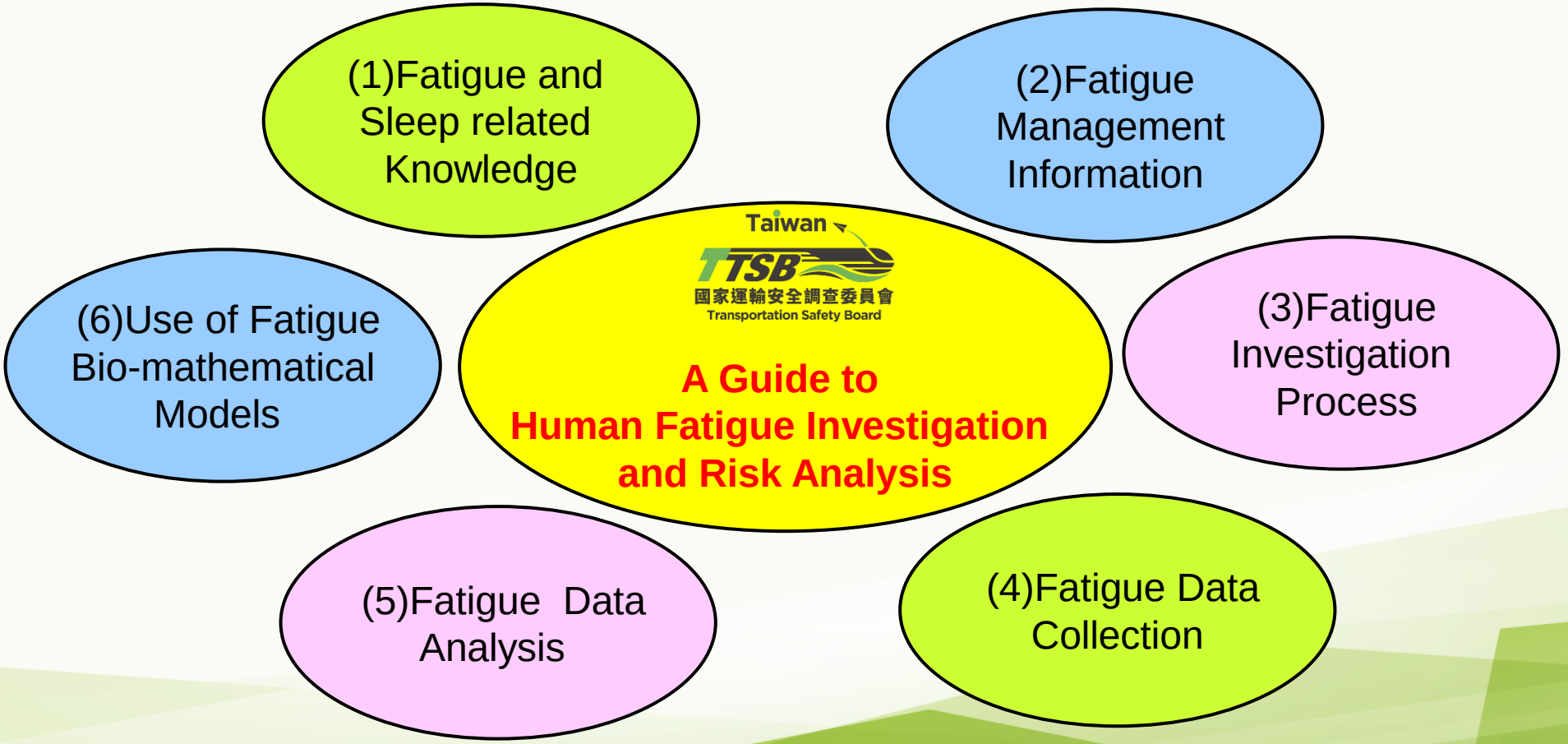
To study the existing fatigue investigation guides which has developed by other organizations

How to Develop the TTSB Fatigue Investigation Guide?

Refer to fatigue related research papers & fatigue management manuals

Consult with aviation medical examiners & university professors who are proficient in fatigue management

To introduce fatigue bio-mathematical models, and study their applications and limitations for investigation


(1)Fatigue and Sleep related Knowledge
(2)Fatigue Management Information
(3)Fatigue Investigation Process
(4)Fatigue Data Collection
(5)Fatigue Data Analysis
(6)Use of Fatigue Bio-mathematical Models
Taiwan
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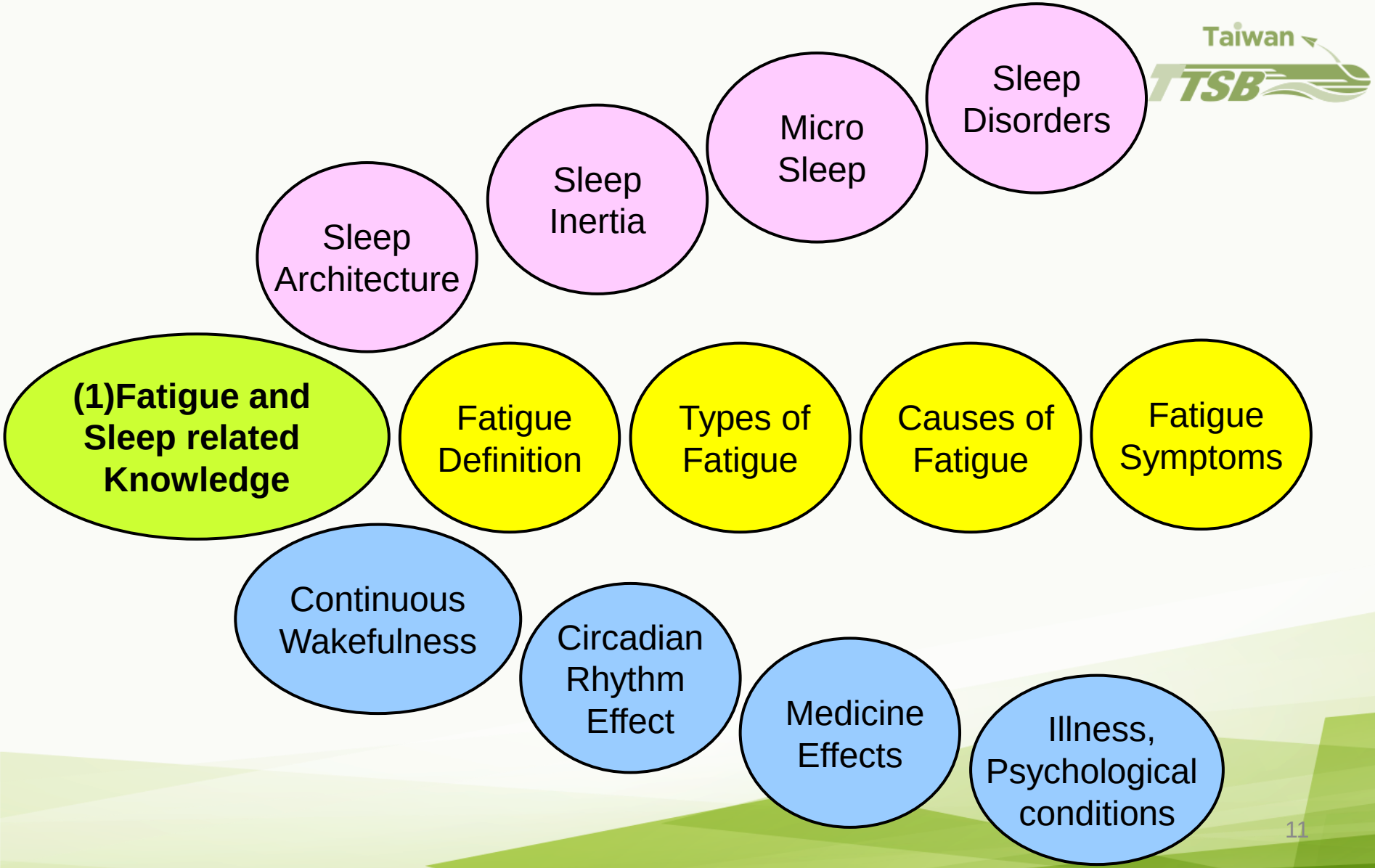
Transportation Safety Board
A Guide to
Human Fatigue Investigation
and Risk Analysis


Taiwan
TTSB
Sleep Disorders
Micro Sleep
Sleep Inertia
Sleep Architecture
(1)Fatigue and Sleep related Knowledge
Fatigue Definition
Types of Fatigue
Causes of Fatigue
Fatigue Symptoms
Continuous Wakefulness
Circadian Rhythm Effect
Medicine Effects
Illness, Psychological conditions

(2)Fatigue Management Information

TSB, Canada 2014

Fatigue prevention | **Fatigue mitigation** | **Fatigue risk assurance**

HAZARD IDENTIFCATION

PREDICTIVE

- Previous experience
- Evidence based scheduling practices
- Bio-mathematical modeling

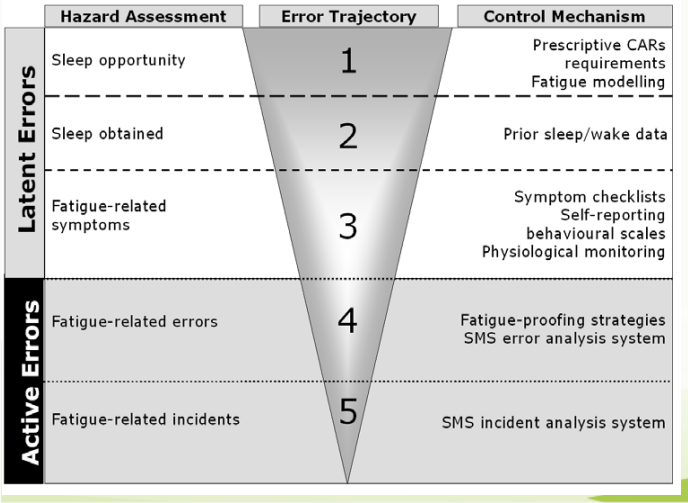
PROACTIVE

- Self-reported fatigue risks
- Fatigue surveys
- Performance data
- Safety databases and scientific studies
- Planned vs. actual time worked analysis
- Sleep monitoring

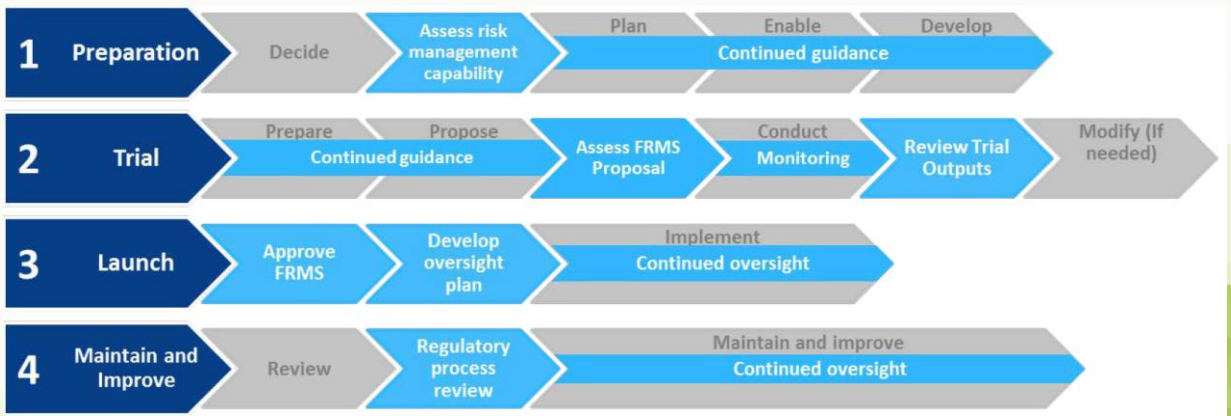
REACTIVE

- Hazard reports
- Operational audits
- Event investigations

Transport Canada 2007



ICAO Doc 9966 2016



(3)Fatigue Investigation Process

Investigating Fatigue Steps

STEP 1

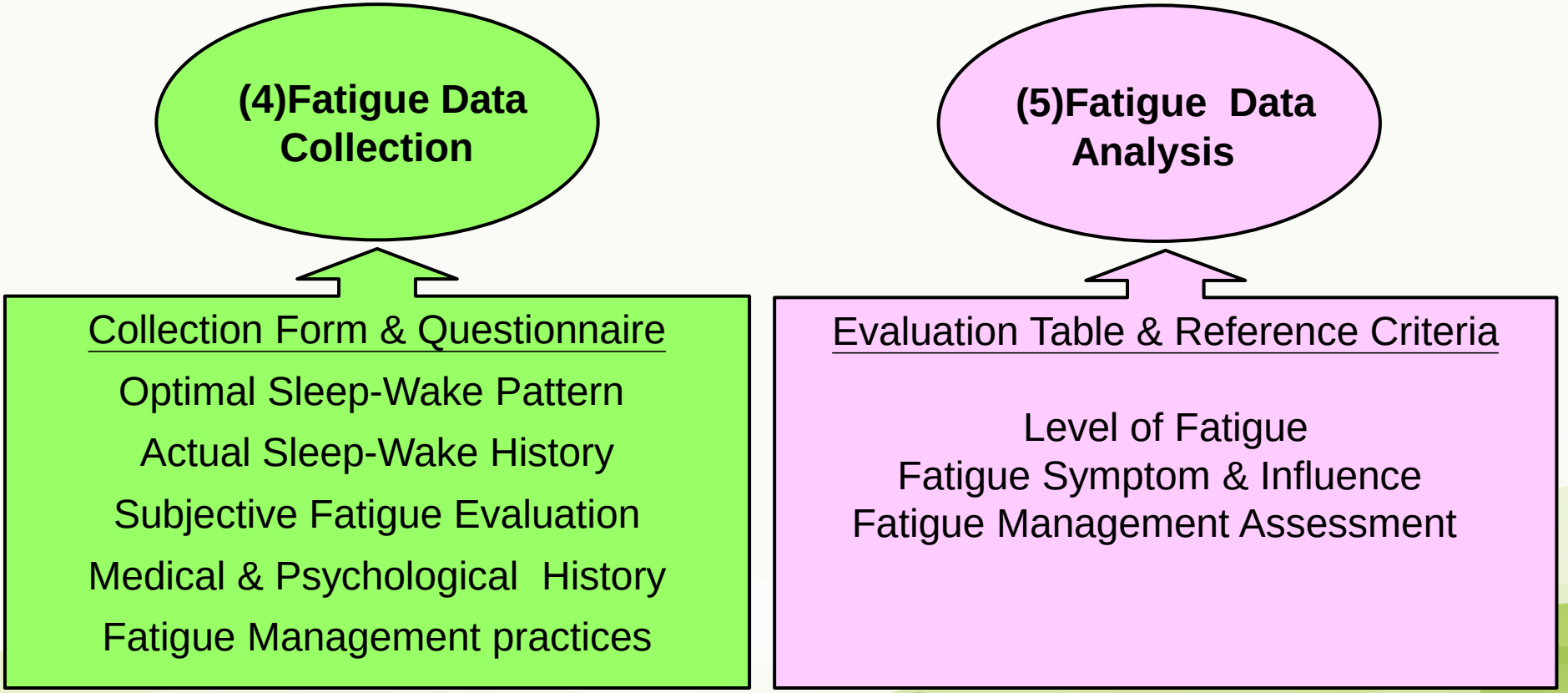
Determine if there is sufficient information to conclude that fatigue was present at a level sufficient to impact performance
(Test for the existence of fatigue causes)

STEP 2

Determine if there is sufficient evidence to conclude fatigue contributed to the human performance
(Test for fatigue influence on human performance)

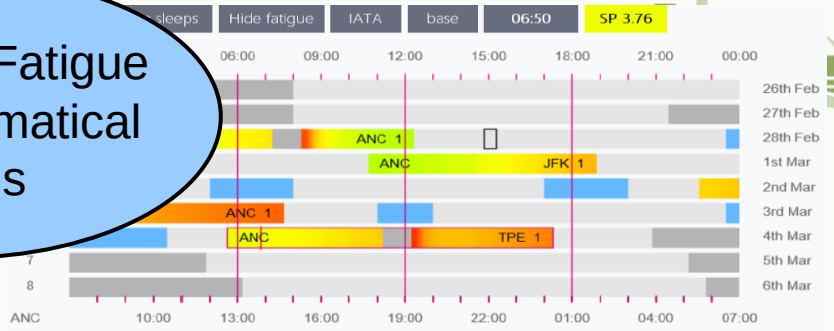
STEP 3

Access availability and effectiveness of fatigue management measures established by the related organizations
(Evaluate the effectiveness of fatigue management)


(4)Fatigue Data Collection
Collection Form & Questionnaire
Optimal Sleep-Wake Pattern
Actual Sleep-Wake History
Subjective Fatigue Evaluation
Medical & Psychological History
Fatigue Management practices
(5)Fatigue Data Analysis
Evaluation Table & Reference Criteria
Level of Fatigue
Fatigue Symptom & Influence
Fatigue Management Assessment

System for Aircrew Fatigue Evaluation (SAFE) FRMSc, UK

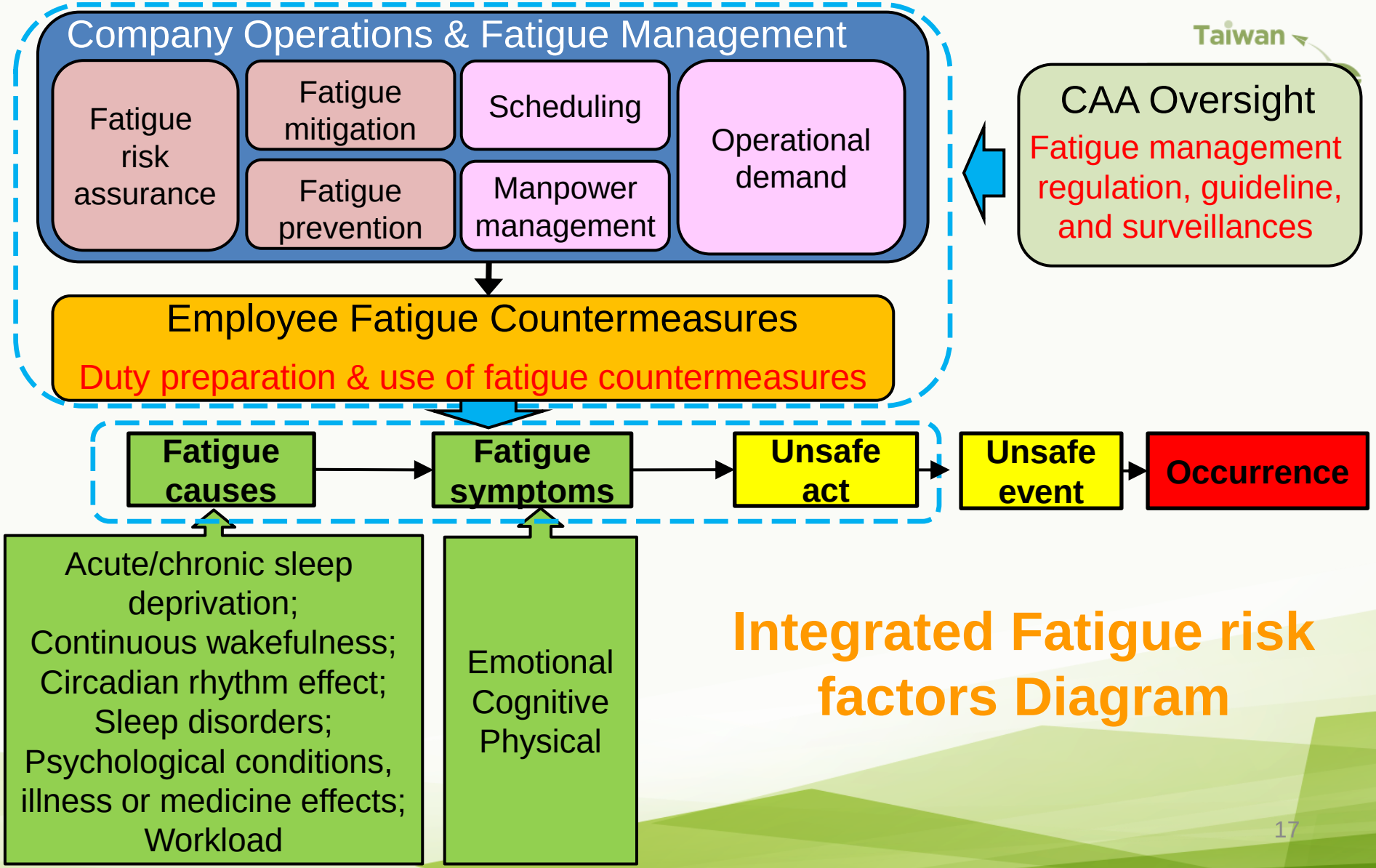
(6)Use of Fatigue Bio-mathematical Models



- Definitions, functions, and limitations of fatigue bio-mathematical models
- User guide of the SAFE to Identify high fatigue level duties in the pilot's rosters

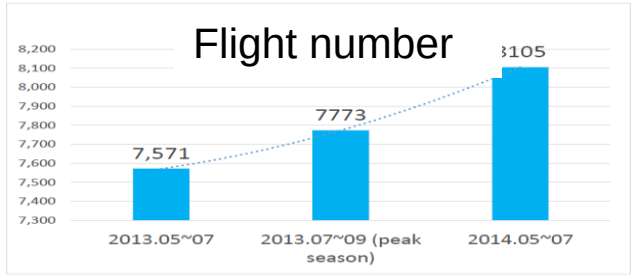
Features	Limit
O Actual sleep period input	X Sleep quality
O 2~4 Crew composition	X Single pilot operations
O flight sectors input (workload factor)	X Sleep disorder
O Sleep inertia considered	X Psychological conditions effect
O In-flight rest considered	X Illness or medicine effects
O In-flight rest facilities	
O Adjustable workload setting	

③ Integrated Fatigue Risk Factors Diagram



Integrated Fatigue risk factors Diagram

Effect of long-term manpower and operational demand conditions on scheduling



Number of revenue flight
Number of training course

Operational demand

V

Manpower

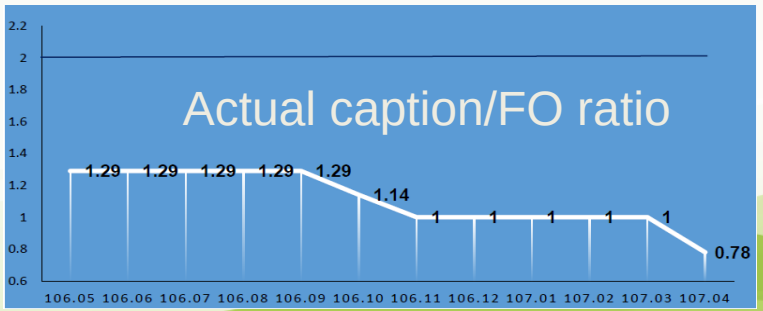
Aircraft/ pilot number ratio
Caption/FO number ratio
Trend of total pilot number

Fatigue level in the Flight duty

Low

High

Effective fatigue management measures

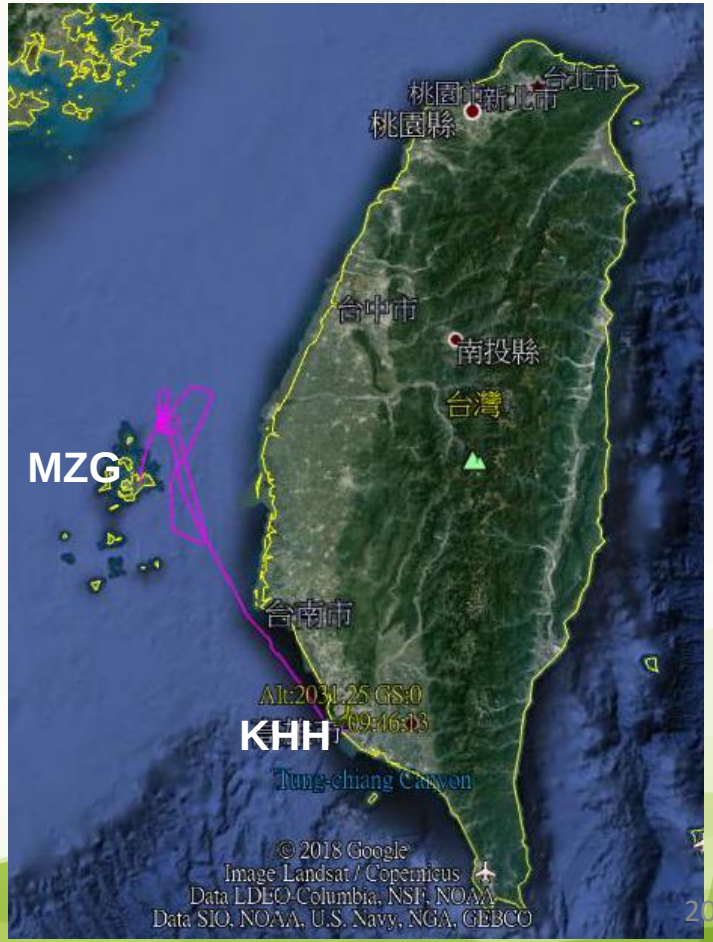


④ Fatigue Issues Related to GE222 CFIT Accident

GE222 CFIT Accident

Background information

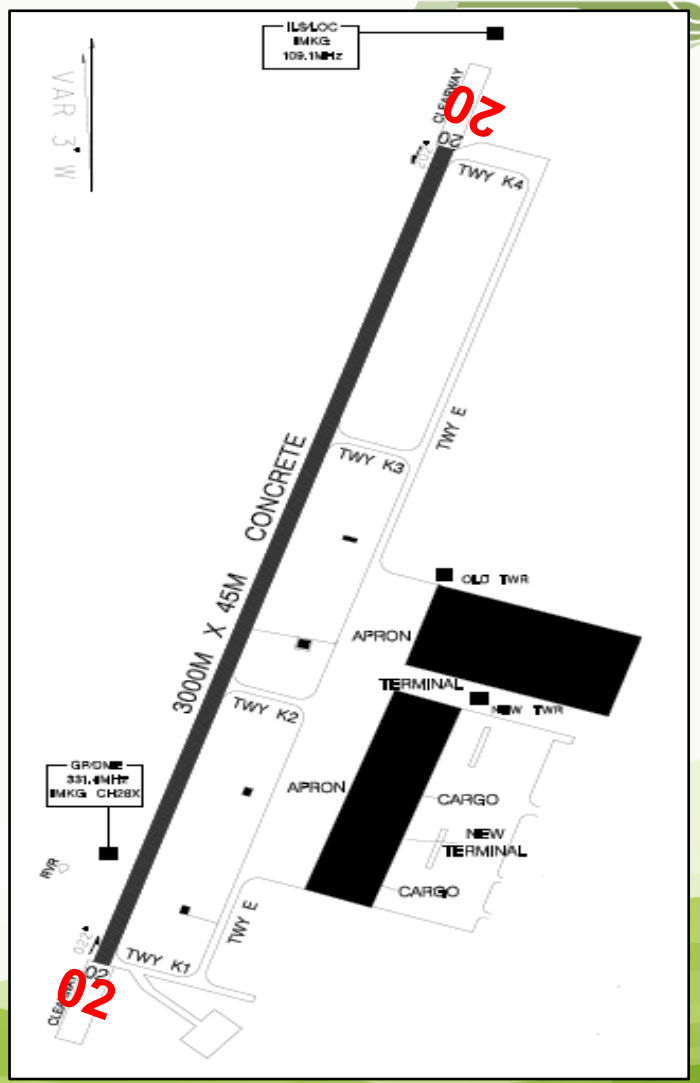
- 23rd July, 2014
- TNA flight GE222
- ATR72-500
- Scheduled PAX flight
- Kaohsiung(KHH) to Magong(MZG, in the Penghu Islands)
- 58 souls on board



MZG Airport

Runway Information

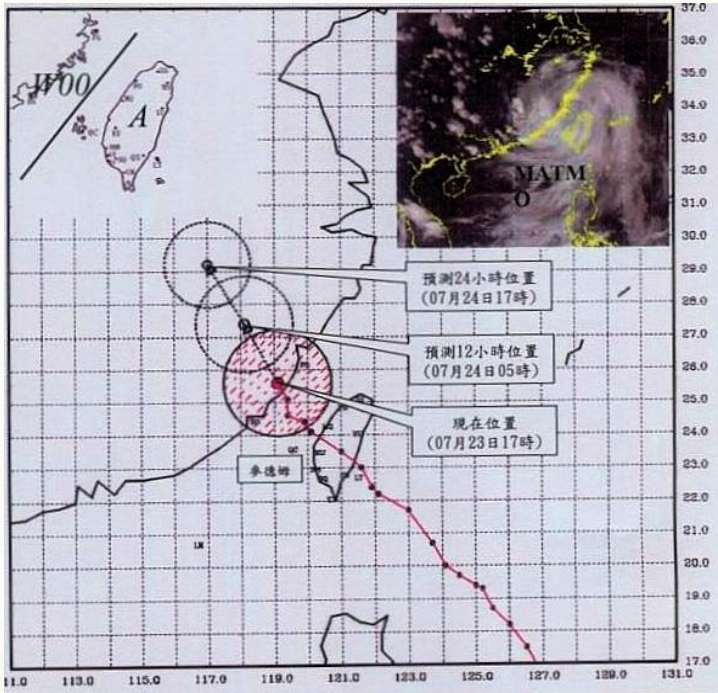
- Single runway designated 02/20
- Active one was RWY20
  - ➢ equipped with a VOR non-precision approach system
  - ➢ landing visibility limitation of 1,600 meters



Weather Condition at MZG

Typhoon “Matmo”

- Moving northwest away from Penghu Islands
- Typhoon warning for MZG was lifted 5 mins before the departure
- Airport was still affected by its outer rainbands



Weather conditions included

- Thunderstorm activities of heavy rain
- Significant changes in visibility
- Changes in wind direction and speed

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History of flight

Flight Progress

- 3rd of the 6 sectors schedule
- Delayed by 1h45m due to poor weather
- Pilots were aware that the visibility (800m) was below landing minima for RWY20 VOR approach
- Decided to proceed, and intended to hold upon arrival until weather conditions improved
- Captain was the PF throughout the flight

History of flight

Flight Progress

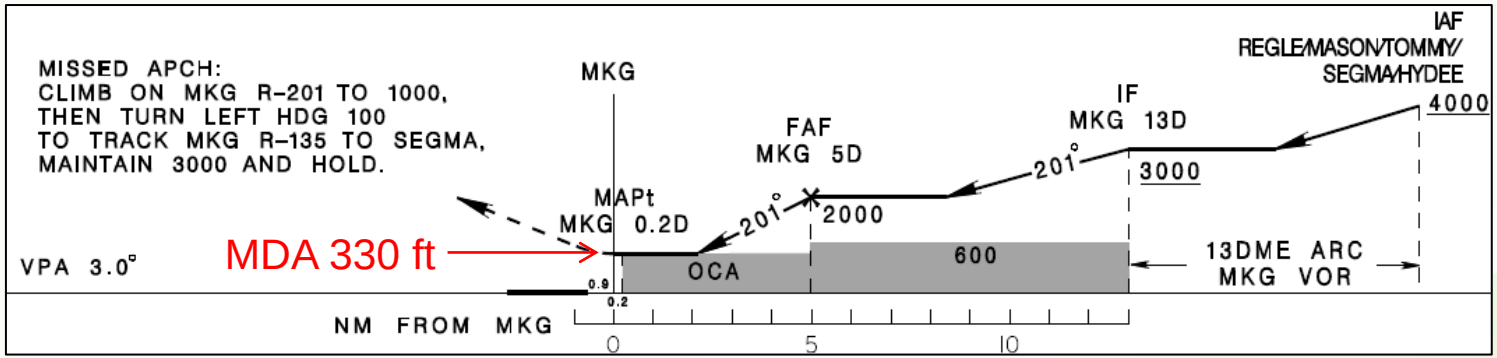
- Vectored by ATC and entered a holding pattern
- After about a 30 mins holding, the visibility for RWY20 had improved to 1,600 meters

- The aircraft was instructed for the approach

The Approach Chart

Profile of MZG RWY20 VOR

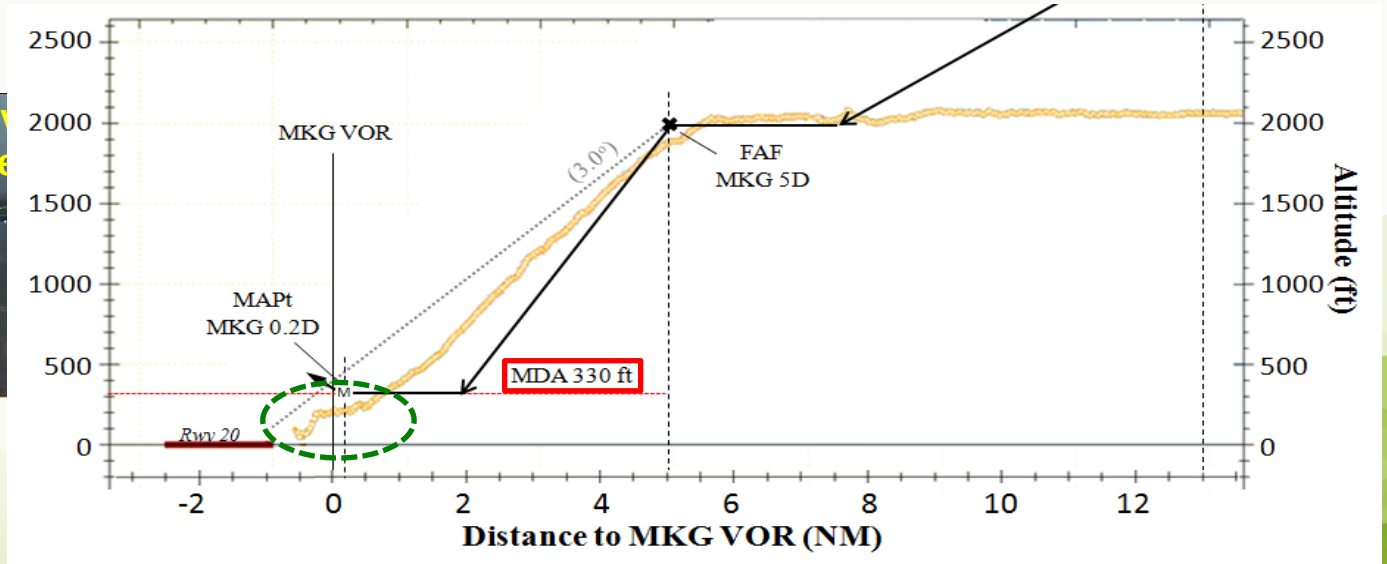
- MDA was at 330 feet
- MAPt was 0.2 NM ahead of MKG VOR station



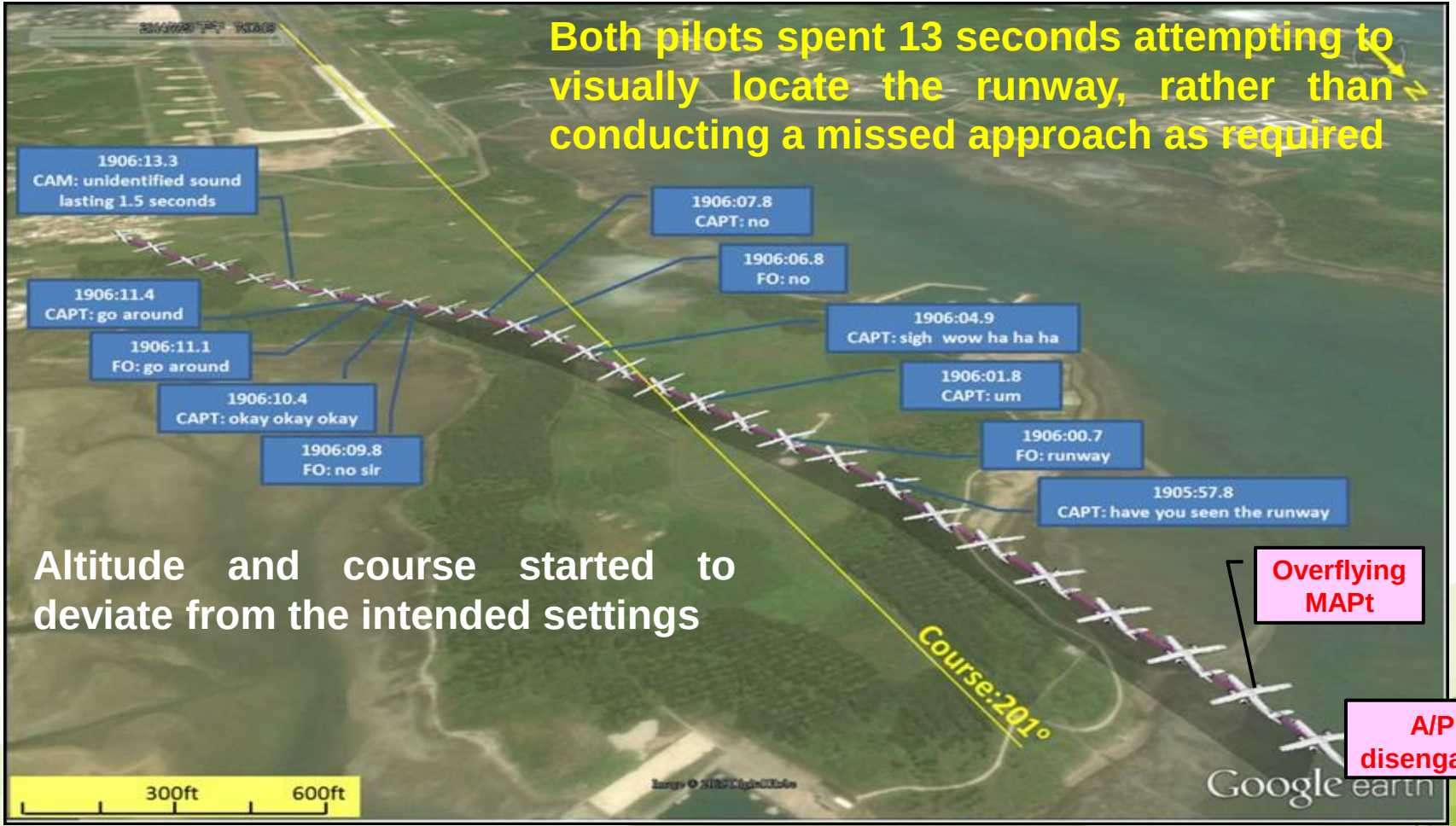
MDA: Minimum Descend Altitude in a non-precision approach that a pilot must not descend below it without the required visual reference.

The Final Approach

- Heavy rain and thunderstorm activity intensified.
- The Captain intentionally descended the aircraft below the MDA in the IMC w/o obtaining the required visual references.
- Intended to maintain 200 feet.



The Final Approach

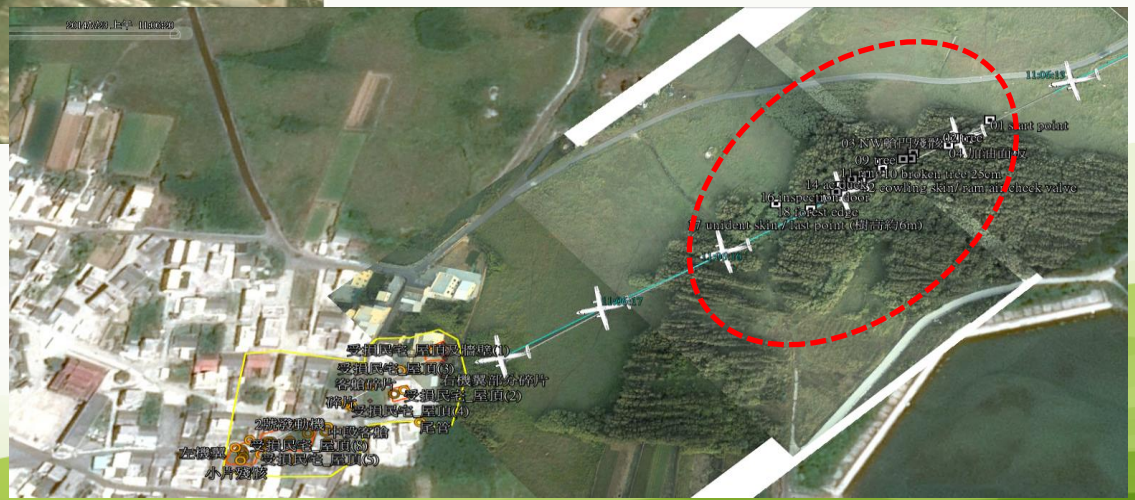


The Final Approach

Go Around Call

- At 72 feet
- Half NM behind the MAPt

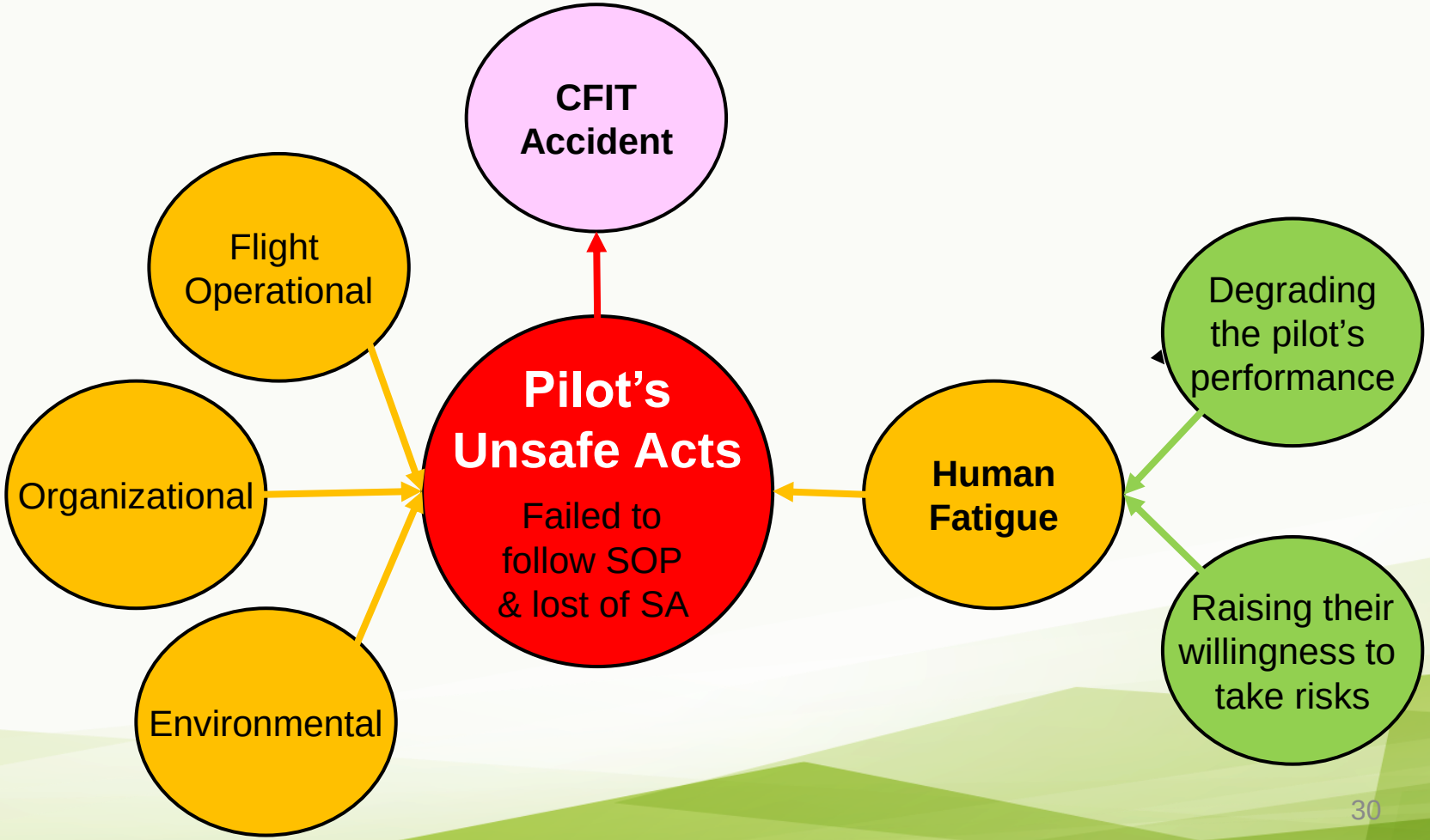
- The aircraft collided with bushes 2 seconds after



The Final Approach

- Aircraft destroyed
- All 4 crew members and 44 passengers sustained fatal injuries

Contributing Factors



Symptoms of Fatigue

Physical	The captain stated he was very tired, and his yawns were detected by the CVR.
Cognitive	The captain displayed lapses of attention, decreased vigilance, and memory errors during the flight. ① lapses in radio communications with ATC; ② incorrect VOR approach course selection; ③ incorrect recall of ATC wind information; ④ incorrect autopilot mode selections
Emotional	The presence of flight crew's risk taking behavior.

Causes of Fatigue

Inconclusive

Sleep Related

- The absence of Wake/Sleep factual data
- The inapplicability of Circadian Rhythm Effect

Inconclusive

Physical & Mental Related

- No anomalies found in relevant medical records

Causes of Fatigue

Workload

Severe weather conditions had increased the stress level of that particular flight.

Operational workload for the pilots was also high as demonstrated by the rosters.

Captain's roster indicated an elevated flying activity where 3-month cumulative flight time kept increasing.

The number of daily sectors had also increased to a max. of 8.

Time Period	2013.05~07	2013.07~09 (Peak season in 2013)	90-day prior to 2014.7.23
Captain's 3-month Cumulative Flight Time	227 hrs	256 hrs	278 hrs
Captain's Max Daily Flight Sectors	6 legs	6 legs	8 legs

Fleet Manpower Management

Three new ATR72-600

	Time Period	2013.05~07	2013.07~09 (Peak season in 2013)	2014.05~07	Trend	
Operating Indicators	Aircraft Number	9	9	10	↑	grew in fleet
	Revenue Flight Number	7,571	7,773	8,105	↑	# of revenue flight
	Training Demand	Normal	Normal	High	↑	training demand
	Pilot Demand	54	54	60+	↑	manpower demand
	Pilot Number	54	53	52	↓	reduction in the # of pilots
Fatigue Risk Factors	Cumulative Flight Time ≧270 hrs	4 pilots	14 pilots	30 pilots	↑	cumulative flight time
	Pilot's Max Daily Flight Sectors	6	6	8	↑	max. daily sectors

Conclusions of Fatigue Analysis

Findings related to risk

At the time of the occurrence, the Captain's performance was probably degraded by his fatigue accumulated from the multiple daily sectors flown and flight times during the months preceding the occurrence.

The operator was aware of the increased operational tempo, but did not assess or mitigate the associated fatigue risks.

Safety Recommendations

To the Operator

Rectify the pilot shortage

Implement an effective fatigue risk management process

Provide flight crew with adequate fatigue management training

Safety Recommendations

To the Regulator

Develop detailed guidance for operators to facilitate a smooth implementation of the fatigue related recommendations

⑤ Conclusions

Conclusions

① The development of a Fatigue Investigation Guide could provide investigators essential knowledge, processes, and tools to collect and analyze fatigue data, make evidence-based conclusions, and raise concrete recommendations.

② Recommend that the Foundation convenes fatigue related experts and further develop a comprehensive fatigue investigation training course based on the existing fatigue related research results.

Thanks for your listening