SAFETY INVESTIGATION REPORT

Malaysia Airlines Boeing B777-200ER (9M-MRO)
08 March 2014

By

The Malaysian ICAO Annex 13 Safety Investigation Team for MH370

The Malaysian ICAO Annex 13
Safety Investigation Team for MH370

Email: *MH370SafetyInvestigation@mot.gov.my*

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II. SYNOPSIS

On 08 March 2014, a scheduled passenger flight from Kuala Lumpur to Beijing, operated by Malaysia Airlines (MAS) and designated flight MH370, went missing soon after a routine handover from the Malaysian Air Traffic Control (ATC) to Viet Nam ATC. The aircraft operating the flight was a Boeing 777-200 ER, registered as 9M-MRO. On board the aircraft were 12 crew and 227 passengers (239 persons in total). A review of available radar and satellite communications indicated that the aircraft flew back across the Malaysian Peninsula and subsequently travelled to the southern Indian Ocean. Despite an extensive air and sea search, the location of the aircraft and occupants remains unknown. However, some debris have been recovered consistent with having drifted over nearly two years from the area in which impact is thought to have occurred.

By international convention, the investigation of aircraft accidents and incidents is conducted in accordance with Annex 13 to the Convention on International Civil Aviation, *Aircraft Accident and Incident Investigation.* The Standards and Recommended Practices (SARPs) in Annex 13 are applied in Malaysia through Part XII of the Malaysian Civil Aviation Regulations (MCAR) 1996.

In accordance with the MCAR 1996, an independent international investigation team (The Team) comprising 19 Malaysians and 7 Accredited Representatives (ARs) of 7 safety investigation authorities from 7 countries was established by the Malaysian Minister of Transport to investigate the disappearance of MH370. The ARs appointed are from the:

- Air Accidents Investigation Branch (AAIB) of United Kingdom
- Australian Transport Safety Bureau (ATSB) of Australia;
- Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (BEA) of France;
- Civil Aviation Administration of the People's Republic of China (CAAC);
- National Transportation Safety Board (NTSB) of United States of America;
- National Transportation Safety Committee (NTSC) of Indonesia; and
- Transport Safety Investigation Bureau (TSIB) of Singapore (formerly Air Accident Investigation Bureau [AAIB]).

Advisors to the ARs were appointed from the States' investigation agencies, as well as the aircraft, engine and satellite communications systems manufacturers.

While this investigation report documents the safety investigation aspects as noted above, the Team is aware of other investigations being undertaken for other purposes, including criminal investigations.

Investigation Organisation

The investigation was organised in accordance with the ICAO Manual of Accident Investigation and Incident Investigation (Doc. 9756-AN965) practices and comprised an Investigator-in-Charge (IIC) and three main Committees, comprising:

- Airworthiness;
- Flight Operations; and
- Medical/Human Factors.

Preliminary Report

On 09 April 2014, the Malaysian Ministry of Transport released the **Preliminary Report** into the investigation activities at that time. The Preliminary Report contained a Safety Recommendation to ICAO in regard to in-flight tracking of large commercial aircraft. A copy of the **Preliminary Report** is available on the Department of Civil Aviation website here:

- *http://www.dca.gov.my/wp-content/uploads/2015/02/Preliminary-Report1.pdf*

1st Interim Statement and Factual Information Report

On 08 March 2015, the Team released the **1st Interim Statement** and a **Factual Information Report** detailing the factual information available at that time. The report contained no analysis, findings/conclusions or safety recommendations. Copies of both the **Interim Statement** and the **Factual Information Report** are available from the Malaysian Ministry of Transport's two websites here:

- *http://mh370.mot.gov.my*
- *http://www.mh370.gov.my*

2nd Interim Statement

On 08 March 2016, the Team released the **2nd Interim Statement**.

3rd Interim Statement

On 08 March 2017, the Team released the ***3rd Interim Statement***.

4th Interim Statement

On 08 March 2018, the Team released the ***4th Interim Statement.***

Safety Investigation Report

This **Safety Investigation Report** (Report) builds on the previous ***Factual Information Report*** and extends the available information publicly released to include analysis, findings/conclusions and safety recommendations. Recognising that at the time of issue of this Report, the main aircraft wreckage, including the aircraft's Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) have not yet been located, this Report will necessarily be limited by a significant lack of evidence.

Based on the available evidence, the analysis of factors considered relevant to the disappearance of MH370 include:

- Diversion from Filed Flight Plan Route;
- Air Traffic Services Operations;
- Flight Crew Profile;
- Airworthiness & Maintenance and Aircraft Systems;
- Satellite Communications;
- Wreckage and Impact Information;
- Organisation and Management Information of DCA and MAS; and
- Aircraft Cargo Consignment.

Other factors examined by the investigation and not considered relevant include the aircraft weight and balance, the amount and quality of fuel on-board and meteorological conditions.

Significant Issues and Safety Recommendations

In the analysis of the above factors, several significant issues were identified that could affect the safety of international commercial aviation, including the lack of effectiveness of certified Emergency Locator Transmitters (ELT) if a large commercial aircraft ditches or crashes into the ocean.

While this issue is currently being addressed by ICAO and the international aviation industry, the Team is of the view that work needs to be expedited in this area to implement effective changes to enhance aviation safety into the future.

Additionally, a number of issues were identified that could affect the monitoring and timely initiation of search and rescue of commercial aircraft in Malaysian airspace by the Air Navigation Services provider. Issues were also identified in the Airline Operations. They include the following:

- Malaysian and adjacent air traffic management;
- Cargo screening;
- Flight crew medical and training records;
- Reporting and following-up of crew mental health;
- Flight following system;
- Quick reference for operations control; and
- Emergency locator transmitter effectiveness.

As a result of the issues identified in the investigation and in accordance with para. 6.8 of Annex 13 which states that: "*At any stage of the investigation of an accident or incident, the accident investigation authority of the State conducting the investigation shall recommend in a dated transmittal correspondence to the appropriate authorities, including those in other States, any preventive action that it considers necessary to be taken promptly to enhance aviation safety",* a number of safety recommendations (*Section 4 - Safety Recommendations),* have been made to the Department of Civil Aviation (DCA), Civil Aviation Authority of Viet Nam, Malaysian Airlines Berhad (MAB, formerly MAS), the Malaysia Airports Holdings Berhad (MAHB) and the International Civil Aviation Organization (ICAO) to enhance aviation safety.

III. DEDICATION

This report is dedicated to the memory of the 239 passengers and crew missing on MH370 (9M-MRO) on 08 March 2014. They will be forever missed by their families, friends and colleagues, but never forgotten.

IV. ACKNOWLEDGEMENT

The Malaysian ICAO Annex 13 Safety Investigation Team for MH370 would like to acknowledge the work carried out by the Search Strategy Group in the analysis of the satellite data and the search teams involved in the search for MH370. The search was unprecedented in its scale and their dedication was a remarkable effort.

We trust that MH370 will be located to provide answers to the families of the passengers and crew of MH370 and bring closure to this event.

V. OBJECTIVE

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

Annex 13, Section 3.1 page 3-1

VI. DISCLAIMER

This **Safety Investigation Report** contains facts which have been determined up to the time of issue and is published to inform the aviation industry and the public of the safety investigation and the safety issues raised thus far. Therefore, the report may be subject to alteration or correction if additional and credible evidence becomes available.

Extracts can be published without specific permission providing that the source is duly acknowledged.

VII. GLOSSARY OF TERMS

When the following terms are used, they have the following meaning:

Accident

An occurrence associated with the operation of an aircraft which, in the case of a manned aircraft, takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, or in the case of an unmanned aircraft, takes place between the time the aircraft is ready to move with the purpose of flight until such time as it comes to rest at the end of the flight and the primary propulsion system is shut down, in which:

a) a person is fatally or seriously injured as a result of:

- being in the aircraft, or
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
- direct exposure to jet blast,

Except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

- adversely affects the structural strength, performance or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component,

  except for engine failure or damage, when the damage is limited to a single engine (including its cowlings or accessories), to propellers, wing tips, antennas, probes, vanes, tires, brakes, wheels, fairings, panels, landing gear doors, windscreens, the aircraft skin (such as small dents or puncture holes), or for minor damages to main rotor blades, tail rotor blades, landing gear, and those resulting from hail or bird strike (including holes in the radome); or

c) The aircraft is missing or is completely inaccessible.

Note 1 - For statistical uniformity only, an injury resulting in death within thirty days of the date of the accident is classified, by ICAO, as a fatal injury.

Note 2 - An aircraft is considered to be missing when the official search has been terminated and the wreckage has not been located.

cont...

Note 3 - The type of unmanned aircraft system to be investigated is addressed in Annex 13, para 5.1.

Note 4 - Guidance for the determination of aircraft damage can be found in Annex 13, Attachment E.

Accredited Representative

A person designated by a State, on the basis of his or her qualifications, for the purpose of participating in an investigation conducted by another State. Where the State has been established an accident investigation authority, the designated accredited representative would normally be from that authority.

Advisor

A person appointed by a State, on the basis of his or her qualifications, for the purpose of assisting its accredited representative in an investigation.

Aeronautical fixed telecommunication network (AFTN)

A worldwide system of aeronautical fixed circuit provided, as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

Air-ground communication

Two-way communication between aircraft and stations or locations on the surface of the earth.

Aircraft

Any machine that can give derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.

Alert Phase

A situation wherein apprehension exists as to the safety of an aircraft and its occupants.

Alerting Post

Any facility intended to serve as an intermediary between a person reporting an emergency and a rescue co-ordination centre or rescue sub-centre.

cont...

Blind Transmission

A transmission from one station to another station in circumstances where two-way communication cannot be established but where it is believed that the called station is able to receive the transmission.

Cabin Crew Member

A crew member who performs, in the interest of safety passengers, duties assigned by the operator or the pilot-in-command of the aircraft, but who shall not act as a flight crew member.

Cargo

Any property carried on an aircraft other than mail, stores and accompanied or mishandled baggage.

Causes

Actions, omissions, events, conditioning, or a combination of thereof, which led to the accident or incident. The identification of causes does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

Co-ordinated Universal Time (UTC)

International term for time at the prime meridian.

Conversion Training

Training required when a pilot is posted to a different aircraft type or model

DETRESFA

The code word used to designate a distress phase

Distress Phase

A situation wherein there is reasonable certainty than an aircraft and its occupants are threatened by grave and imminent danger or require immediate assistance.

Emergency Phase

A generic term meaning, as the case may be, uncertainty phase, alert phase or distress phase

cont...

Filed Flight Plan

The flight plan as filed with an ATS unit by the pilot or a designated representative, without any subsequent changes.

Flight Plan

Specified information provided to air traffic units, relative to an intended flight or portion of a flight of an aircraft.

Flight Recorder

Any type of recorder installed in the aircraft for the purpose of complementing accident/incident investigation - *Annex 6, Parts I, II and III, for specifications relating to flight recorders.*

Incident

An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

Note: *The types of incidents which are of main interest to the International Civil Aviation Organization for accident prevention studies are listed in Accident/Incident Reporting Manual (Doc. 9156).*

Investigation

A process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and/or contributing factors and, when appropriate, the making of safety recommendations.

Investigator-in-Charge

A person charged, on the basis of his or her qualifications, with the responsibility for the organisation, conduct and control of an investigation

Note - *Nothing in the above definition is intended to preclude the functions of an investigator-in-charge being assigned to a commission or other body.*

Knot (kt)

A unit of speed equal to one nautical mile per hour.

cont...

NOTAM

A notice distributed by means of telecommunication containing information concerning the establishment, condition of change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

Operator

A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Pilot-in-Command

The pilot responsible for the operation and the safety of the aircraft during flight time.

Safety Recommendation

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident. In addition to safety recommendations arising from accident and incident investigations, safety recommendations may result from diverse sources, including safety studies. *(Annex 13, Chapter 1, page 1-3).*

State of Design

The State having jurisdiction over the organization responsible for the type design.

State of Manufacture

The State having jurisdiction over the organization responsible for the final assembly of the aircraft.

State of Occurrence

The State in the territory of which an accident or incident occurs.

State of the Operator

The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence.

cont...

State of Registry

The State on whose register the aircraft is entered.

<u>Note</u>: *In the case of the registration of aircraft of an international operating agency on other than a national basis, the States constituting the agency are jointly and severally bound to assume the obligations which, under the Chicago Convention, attach to a State of Registry. See, in this regard, the Council Resolution of 14 December 1967 on Nationality and Registration of Aircraft Operated by International Operating Agencies which can be found in Policy and Guidance Material on the Economic Regulation of International Air Transport (Doc 9587).*

State Safety Programme (SSP)

An integrated set of regulations and activities aimed at improving safety.

Uncertainty Phase

A situation wherein doubt exists as to the safety of an aircraft or marine vessel, and of the persons on board.

VIII. ABBREVIATIONS & CODES

A

A300	Airbus 300
A/P	Autopilot
A-SAR	Aeronautical Search and Rescue
A/T	Autothrottle
AAIB	Air Accidents Investigation Branch (United Kingdom)
AC	Alternating Current
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACD	Airways Clearance Delivery
ACE	Actuator Control Electronic
ACIPS	Airfoil Cowl Ice Protection System
ACMP	Alternating Current Motor Pump
ACMS	Aircraft Condition Monitoring System
ACP	Audio Control Panel
AD	Airworthiness Directive
ADF	Automatic Direction Finder
ADFR	Automatic Deployable Flight Recorder
ADI	Attitude Director Indicator
ADIRS	Air Data Inertial Reference System
ADIRU	Air Data Inertial Reference Unit
ADM	Airworthiness Departmental Manual
ADP	Air Driven Pump
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
AED	Airworthiness Engineering Division
AEG	Airline Engineering Group
AES	Airborne Earth Station
AFD	Assistant Flight Data
AFDC	Autopilot Flight Director Computer
AFDS	Autopilot Flight Director System
AFS	Aeronautical Fixed Service
AFTN	Aeronautical Fixed Telecommunication Network
AIC	Aeronautical Information Circular
AID	Airworthiness Inspection Division
AIMS	Airplane Information Management System
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service

A ***(cont…)***

A (cont...)

ALERFA	Alert Phase
ADF	Automatic Direction Finder
ALR	Alerting
ALT	Altitude
AM	Amplitude Modification
AMC	Acceptable Means of Compliance
AMEL	Aircraft Maintenance Engineer's Licence
AMO	Approved Maintenance Organisation
AMU	Audio Management Unit
AN	Aircraft Number; Airworthiness Notice
ANS	Air Navigation Services
AOA	Angle of Attack
AOC	Air Operator Certificate
AOR	Area of Responsibility
APP	Approach
APU	Auxiliary Power Unit
APUC	Auxiliary Power Unit Controller
AR	Accredited Representative/s
AR	Approach Radar
ARCC	Aeronautical Rescue Coordination Centre
ARSC	Aeronautical Rescue Sub-Centre
ARINC	Aeronautical Incorporated
ASB	Amanah Saham Bumiputra (A People's Trust Council of the Malaysian Government)
ASDI	Aircraft Situation Display Information
ASL	Air Service Licence
ASN	Amanah Saham Nasional (a Government-back National Trust Fund)
ASR	Air Safety Report
ASCPC	Air Supply Cabin Pressure Controller
ATC	Air Traffic Control
ATC	Air Traffic Controller/s
ATC-ATO	Air Traffic Control - Approved Training Organisation
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Officer
ATD	Actual Time of Departure
ATI	Air Traffic Inspectorate
ATIS	Automatic Terminal Information Broadcast
ATM	Air Traffic Management
ATSB	Australian Transport Safety Bureau
ATN	Aeronautical Telecommunication Network
ATO	Approved Training Organisation

A *(cont).*

A *(cont...)*

ATPL	Air Transport Pilot Licence
ATS	Air Traffic Services
ATSC	Air Traffic Services Centre
ATSU	Air Traffic Service Unit
ATTN	Attenuator
AUTO	Automatic
AVBL	Available
AWL	Airworthiness Limitation
AWY	Airway

B

BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (France)
BER	Bit Error Rate
BEW	Basic Empty Weight
BFO	Burst Frequency Offset
BKK	IATA Airport Designator for Suvarnahbumi International Airport
BITE	Built In Test Equipment
BOI	Board of Inquiry
BSCU	Brake System Control Unit
BSU	Beam Steering Unit
BTO	Burst Timing Offset

C

C	Degree Celsius (Centigrade)
C of A	Certificate of Airworthiness
C of G	Centre of Gravity
C of R	Certificate of Registration
CA	Collective Agreement
CAA	Civil Aviation Act
CAAC	Civil Aviation Authority of the Republic of China
CAAS	Civil Aviation Authority Singapore
CAM	Cockpit Area Microphone
CAR 1996	Civil Aviation Regulations 1996

A *(cont...)*

CAR 2016	Civil Aviation Regulations 2016
CAS	Calibrated Airspeed
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Requirements
CAT	Clear Air Turbulence
CB	Circuit Breaker
CCD	Cursor Control Device
CCTV	Closed Circuit Television
CDS	Central Deposit System
CDU	Control Display Unit
CEO	Chief Executive Officer
CHIRPS	Confidential Human Factors Accident Incident Reporting System
CLB	Climb
Cm	Centimetre
CMCS	Central Maintenance Computing System
CMR	Certificate Maintenance Requirement
CMS	Central Maintenance System
COSPAS	Space System for Search of Vessels in Distress
CPA	Crew Performance Appraiser
CPDLC	Controller Pilot Data Link Communications
CPL	Commercial Pilot Licence
CPM	Core Processor Module
CPMU	Cabin Passenger Management Unit
CRM	Crew Resource Management
CRZ	Cruise
CSR	Cabin Safety Report
CTR	Control Zone
CTRL	Control
CTU	Cabin Telecommunications Unit
CVR	Cockpit Voice Recorder
CX	C Extended
CWP	Controller Working Position

D

DARD	Direct Access Radar Data
dB	decibel

A *(cont...)*

A *(cont...)*

DC	Direct Current
DCGF	Data Conversion Gateway Function
DCMF	Data Communication Management Function
DCMS	Data Communication Management System
Deg	Degree
DEOR	Daily Engineering Operations Report
DES	Descent
DETRESFA	Distress Phase
DFDAF	Digital Flight Data Acquisition Function
DFDAU	Digital Flight Data Acquisition Unit
DG	Dangerous Goods
DGCA	Director General of Civil Aviation
DGTA	General Delegate of Armament Aeronautical Technique
DIP	Diplexer
DLNA	Diplexer Low Noise Amplifier
DME	Distance Measuring Equipment
DOW	Dry Operating Weight
DTG	Date-Time-Group

E

EASA	European Aviation Safety Agency
ECL	Electronic Checklist
EDIU	Engine Data Interface Unit
EDP	Engine Driven Pump
EEC	Electronic Engine Control
EFIS	Electronic Flight Instrument System
EFS	Electronic Flight Strips
EHM	Engine Health Monitoring
EICAS	Engine Indicating and Crew Alerting System

E (cont...)

ELMS	Electrical Load Management System

E *(cont…)*

ELP	English Language Proficiency
ELT	Emergency Locator Transmitter
EMD	Engineering & Maintenance Department
EMS	Engineering Maintenance System
ENR	En-route
EOL	End-of-Lease
EEZ	Exclusive Economic Zone
EPF	Employees Provident Fund
EPR	Engine Pressure Ratio
EQIS	Fuel Quantity Indicating System
EST	Estimate
ETA	Estimated Time of Arrival
ETOPS	Extended Twin Engine Operations
EXT	External

F

FAA	Federal Aviation Administration
FANS 1/A	Future Air Navigation System 1/A
FAR	Federal Aviation Regulations
FDEVSS	Flight Deck Entry Video Surveillance System
FDP	Flight Data Processing/Flight Duty Period
FDR	Flight Data Recorder
FFS	Flight-Following System
FPL	Filed Flight Plan (*message type designator – used in AFS message)*
FIR	Flight Information Region
FIS	Flight Information Service
FL	Flight Level
FMC	Flight Management Computer
FLCH	Flight Level Change
FMCF	Flight Management Control Function
FMCS	Flight Management Control System
FMS	Flight Management System
FO	Flight Officer

F *(cont…)*

F (cont…)

FOQA	Flight Operations Quality Assurance
FOS	Flight Operations Sector
FOSI	Flight Operations Surveillance Inspector
FPA	Flight Path Angle
FSCU	Flap Slat Control Unit
FSEU	Flap Slat Electronic Unit
FPS	Flight Progress Strip
FS	Flight Steward
FSS	Flight Stewardess
ft	Feet (*dimensional unit*)
FTL	Flight Time Limitation

G

G/S	Glide Slope
GA	Go Around
GADSS	Global Aeronautical Distress and Safety System
GCC	Golden Class Club
GEN	Generator
GES	Ground Earth Station
GHz	Giga Hertz
GM	Guidance Material
GMT	Greenwich Mean Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GSP	Ground Service Provider
GSR	Ground Safety Report
GWT	Gross Weight

H

hPa	Hectopascal
HPA	High Power Attenuator
HCM	IATA Airport Designator for Ho Chi Minh International Airport
HDG	Heading
HF	High Frequency
HF/AMSS	High Frequency Aeronautical Mobile Service Station
HGA	High Gain Antenna
HLCS	High Lift Control System
HPA	High Power Amplifier
HR	Hours
HYDIM	Hydraulic Interface Module
Hz	Hertz
HZR	Hazard Report

I

i.u.	Index unit
IAMSAR	International Aeronautical and Maritime Search and Rescue
IMARSAT	International Mobile Satellite Organisation
IAS	Indicated Airspeed
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ID	Identification
IDG	Integrated Drive Generator
IFE	In-flight Entertainment
IFS	In-flight Supervisor
IGV	Inlet Guide Vane
ILS	Instrument Landing System
IMO	International Maritime Organisation
In.	Inches
INCERFA	Uncertainty Phase
IOM	Input/output Module
IOR	Indian Oceanic Region
IRP	Incident Review Panel
IRP	Integrated Refuel Panel
ISLN	Isolation

J

JATCC	Joint Air Traffic Control Centre

K

KHz	Kilo Hertz
KLIA	KL International Airport
kg	Kilogram
KPI	Key Performance Indicator
kt	Knot
km^2	Kilometer square
KVA	Kilo Volt Ampere

L

LAME	Licenced Aircraft Maintenance Engineer
LAT	Latitude
lb	Pound
LDW	Landing Weight
LFA	Langkawi Flying Academy
LGA	Low Gain Antenna
LH	Left Hand
LLAR	Lower Lobe Attendant Rest
LNA	Low Noise Amplifier
LNAV	Lateral Navigation
LOA	Letters of Agreement
LOC	Localiser
LONG	Longitude

L (cont...)

LOPA	Lay Out of Passenger Accommodation
LOSA	Line Operations Safety Audit
LRM	Line Replaceable Module
LRU	Line Replaceable Unit
LS	Leading Steward
LSS	Leading Stewardess
LR	Lumpur Radar
LT	Lumpur Tower

M

M	Metre
MAB	Malaysia Airlines Berhad (formerly MAS)
MAC	Mean Aerodynamic Chord
MAHB	Malaysia Airports Holdings Berhad
MAL	Malaysia Airways Limited
MARA	Majlis Amanah Rakyat (An agency of the Malaysian Government)
MAS	Malaysia Airlines (now Malaysia Airlines Berhad [MAB])
MASEU	Malaysia Airlines Employees Union
MATS	Manual of Air Traffic Services
MCC	Maintenance Control Centre
MCDU	Multi-purpose/function Control Display Unit
MCE	Malaysian Certificate of Education
MCP	Mode Control Panel
MEC	Main Equipment Centre
MEL	Minimum Equipment List
MET	Meteorological or meteorology
METAR	Aerodrome routine meteorological report
MFA	Malaysian Flying Academy
MFD	Multi-Function Display
MGSCU	Main Gear Steering Control Unit
MHz	Megahertz
Min	Minute

M (cont.)

MMEA	Malaysian Maritime Enforcement Agency
MMOE	Maintenance Management Organisation Exposition
MNPS	Minimum Navigation Performance Specification
MOC	MAS Operations Centre
MOR	Mandatory Occurrence Report
MOU	Memorandum of Understanding
MPD	Maintenance Planning Document
MR1	Maintenance Report 1
MR2	Maintenance Report 2
MRB	Maintenance Review Board
MRO	Maintenance Repair and Overhaul
MRCC	Maritime Rescue Coordination Centre
MRSC	Maritime Rescue Sub-Centre
ms	meter per second
MSA	Malaysia-Singapore Airlines
MSRR	Maritime Search and Rescue Region
MTSAT	Multifunctional Transport Satellites of Japan Meteorological Agency (JMA)
MU	Management Unit
MYT	Malaysia Time

N

NCR	Non Compliance Record
ND	Navigation Display
NDB	Non-directional Beacon
NDT	Non Destructive Testing
nm	Nautical Mile
NOTAM	Notice to Airmen
NOTOC	Notice to Crew
NSC	National Security Council
NTC	Notes to Crew
NTSB	National Transportation Safety Board (United States of America)
NTSC	National Transportation Safety Committee (Indonesia)

O

OCC	Operations Control Centre
OCXO	Oven Controlled Crystal Oscillator
ODA	Organization Designation Authorisation
OPR	Operator
OPS	Operations
OOOI	Out, Off, On, In

P

P/N	Part Number
PAN-ATM	Procedures for Air Navigation Services - Air Traffic Management
PASS	Passenger(s)
PBN	Performance-based Navigation
PCU	Power Control Units
PDS	Primary Display System
PDU	Power Drive Unit
PFC	Primary Flight Computer
PFCS	Primary Flight Control System
PFD	Primary Flight Display
PIC	Pilot in Command
PLN	Flight Plan
PMG	Permanent Magnet Generator
POA	Production Organisation Approval
POB	Person on Board
POR	Pacific Oceanic Region
ppm	parts per million
PSA	Power Supply Assembly
PSEU	Proximity Switch Electronic Unit
psi	Pounds per square inch
PSR	Primary Surveillance Radar
PSU	Passenger Service Unit
PTT	Push to Talk
PWR	Power
PWS	Predictive Windshear

Q

QA	Quality Assurance
Q & A	Questions and Answers
QAE	Quality Assurance Engineer

R

RAT	Ram Air Turbine
RCC	Rescue Coordination Centre
RDP	Radar Data Plot
REF	Reference
RF	Radio Frequency
RF ATTN	Radio Frequency Attenuator
RFS	Radio Frequency Splitter
RFU	Radio Frequency U nit
RH	Right Hand
RHP	Radar Data Head Processor
rms	Root Mean Square
R n R	Rest and Recreation
RTP	Radio Tuning Panel
RVSM	Reduced Vertical Separation Minima
RQS	Request Supplementary Flight Plan
RADAR	Radio Detection and Ranging
RSC	Rescue Sub-Centre
RMAF	Royal Malaysia Air Force
RNAV	Area Navigation
RTP	Radio Tuning Panel
RVSM	Reduced Vertical Separation Minima
RWY	Runway

S

SAP	Safety Awareness Programme
SAR	Search and Rescue
SAREX	Search and Rescue Exercise
SARPs	Standard and Recommended Practices
SARSAT	Search and Rescue Satellite-Added Tracking
SAT	Static Air Temperature
SATCOM	Satellite Communications
SC	SAR Coordinator
SCP	Safety Change Process
SCSC	South China Sea Corridor
SDU	Satellite Data Unit
SEA 1	South East Asia 1
SEA 2	South East Asia 2
SEL	Select
SELCAL	Selective Calling System
SEP	Safety Engineering Procedures
SIGMET	Significant meteorological information
SIGWX	Significant weather chart
SMC	Search and Rescue Mission Coordinator
SME	Site Maintenance Engineer
SOC	Statement of Compliance
SOI	Supplementary Operations Instructions
SOP	Standard Operating Procedures
SPD	Speed
SR	Safety Recommendations
SRB	Safety Review Boards
SRR	Search and Rescue Region
SSM	Sign Status Matrix
SSP	State Safety Programme
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
STRIDE	Science & Technology Research Institute for Defence
SZB	Subang Airport

T

T	Tonne
TAC	Thrust Augmentation Computer
TAT	Total Air Temperature
TCAS	Traffic Collision Avoidance System
TCP	Transfer of Control Point
THDG	True Heading
TMA	Terminal Control Area
TMCF	Thrust Management Computing Function
THR	Thrust
THR REF	Thrust Reference
TMCF	Thrust Management Control Function
TO	Take-off
TOTFW	Total Remaining Fuel Weight
TRE	Type Rating Examiner
TRI	Type Rating Instructor
TRK	Track
TRTO	Type Rating Training Organization
TRU	Transformer Rectifier Unit
TSIB	Transport Safety Investigation Bureau of Singapore (formerly Air Accident Investigation Bureau [AAIB])
TSO	Technical Standard Order

U

UA	Unstabilized Approach
UAI	Unit Administrative Instruction
UHF	Ultra High Frequency
ULB	Underwater Locator Beacon
ULD	Unit Load Device
USB	Upper Side Band
UTC	Coordinated Universal Time

V

V	Volt
V/S	Vertical Speed
VAAC	Volcanic Ash Advisory Centre
VDL	VHF Digital Link
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF Omni Directional Radio Range

W

W	Watt
WAFC	World Area Forecast Centre
WHCU	Window Heat Control Unit
WINDIR	Wind Direction
WINDSP	Wind Speed
WMKC	ICAO 4-letter location indicator for Kota Bharu Airport
WMKK	ICAO 4-letter location indicator for KL International Airport WMKN
WMKN	ICAO 4-letter location indicator for Kuala Terengganu Airport
WMKP	ICAO 4-letter location indicator for Penang International Airport
WS	Watch Supervisor
WSSS	ICAO 4-letter location indicator for Changi International Airport Singapore
WWW	Worldwide web
WXR	Weather (Meteorological messages)
WX	Weather

X
-
Y
-
Z

ZBAA	ICAO 4-letter location indicator of Peking-Capital International Airport
ZFW	Zero Fuel Weight
Z	Coordinated Universal Time (*in meteorological messages)*

IX. THE MALAYSIAN ICAO ANNEX 13 SAFETY INVESTIGATION TEAM FOR MH370 (9M-MRO)

- **The Malaysian Members**

Dato' Ir. Kok Soo Chon	Investigator-in-Charge
Capt. Abdul Wahab Ibrahim	Senior Investigator/ Chairman of Operations Committee
Mr. Mohan Suppiah	Senior Investigator/ Chairman of Airworthiness Committee
Datuk Dr. Mohd Shah Mahmood	Senior Investigator/ Chairman of Medical/Human Factors Committee
Assoc. Prof. Ir. Abu Hanifah Hj Abdullah	Investigator, Airworthiness
Mr. Amirudin Ab Ghani	Investigator, Airworthiness
Mr. Aslam Basha Khan	Investigator, Airworthiness
Dato' Capt. Jalil Mat Dom	Investigator, Operations
Mr. Khaw Sim Min	Investigator, Operations
Ms. Khoo Lay See	Investigator, Medical/Human Factors
Mr. Lim Kim Seang	Investigator, Operations
Dato' SAC Mohd Rafique Ramli Ariffin	Investigator, Operations
Mr. Muhammad Imran Ismail	Investigator, Operations
Ms. Norwalena Abdul Wahab	Investigator, Operations
Prof. Dr. Pathmanathan Rajadurai	Investigator, Medical/Human Factors
Dato' Dr. Suarn Singh A/L Jasmit Singh	Investigator, Medical/Human Factors
Ms. Swandra Kim Chu Ramachandran	Investigator, Operations (from January 2018)
Mr. Tan Huvi Vein	Investigator, Operations
Dr. Toh Chin Lee	Investigator, Medical/Human Factors
Capt. Abdul Razak Hashim	Investigator, Operations (April 2014 - April 2015)

- **The Accredited Representatives**

Air Accidents Investigation Branch (AAIB)	United Kingdom
Australian Transport Safety Bureau (ATSB)	Australia
Bureau d'Enquêtes et d'Analyses pour la sécurité d l'aviation civile (BEA)	France
Civil Aviation Administration of the People's Republic of China	China
National Transportation Safety Board (NTSB)	United States of America
National Transportation Safety Committee (NTSC)	Indonesia
Transport Safety Investigation Bureau (TSIB) (*formerly Air Accident Investigation Bureau [AAIB])*	Singapore

SECTION 1 – FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

1.1.1 Introduction

On 07 March 2014 at 1642 UTC[1] [0042 MYT, 08 March 2014], Malaysia Airlines (MAS) Flight MH370 Beijing-bound international scheduled passenger flight departed from Runway 32 Right, KL International Airport (KLIA) with a total of 239 persons on board (227 passengers and 12 crew). The aircraft was a Boeing 777-200ER, registered as 9M-MRO.

The Pilot-in-Command (PIC) signed in for duty at 1450 UTC [2250 MYT], 07 March 2014 followed by the First Officer (FO) who signed in 25 minutes later. The MAS Operations Despatch Centre (ODC) released the flight at around 1515 UTC [2315 MYT].

The PIC, an authorised examiner for the Department of Civil Aviation (DCA), Malaysia, was conducting the last phase of line training for the FO, who was transitioning to the Boeing 777 (B777) aircraft type from the Airbus A330. As the FO was certified functional during his last line training flight, no additional pilot was required as safety pilot on MH370. It has been established that the PIC had assigned the FO to be the Pilot Flying for this flight.

The PIC ordered 49,100 kilograms (kg) of fuel for the flight that gave an endurance of 07 hours and 31 minutes including reserves (as per computerised flight plan). The planned flight duration was 05 hours and 34 minutes.

The recorded radio transmissions between the Air Traffic Controllers at Kuala Lumpur Area Control Centre (KL ACC) and the FO showed that an airways clearance request to Lumpur Airways Clearance Delivery was made at 1625:52 UTC [0025:52 MYT] and a pushback and start clearance request to Lumpur Ground was made at 1627:37 UTC [0027:37 MYT].

<u>Note</u>:

In accordance with the Standard Operating Procedures (SOP) of MAS, radio

[1] Unless specified, all times in this report are in Coordinated Universal Time (UTC). The Malaysian Time (MYT) is UTC+08 hours.

communication on the ground is the responsibility of the FO. In the air, the role is reversed when the assigned pilot flying is the FO.

Lumpur Tower cleared MH370 for take-off at 1640:37 UTC [0040:37 MYT]. At 1642:53 UTC [0042:53 MYT] Lumpur Departure cleared MH370 to climb to Flight Level (FL) 180 (the aviation term for 18,000 feet [ft.]) and to cancel the Standard Instrument Departure (SID) clearance by tracking direct to waypoint[2] IGARI.

At 1643:31 UTC [0043:31 MYT], KL ACC Sector 3 Planner coordinated with Ho Chi Minh (Viet Nam) Area Control Centre (HCM ACC) on the Direct Speech Circuit (direct telephone line) relaying the estimated time of arrival (ETA) of MH370 for waypoint IGARI as 1722 UTC [0122 MYT] and the assigned Secondary Surveillance Radar (SSR) transponder code A2157.

MH370 was transferred to Lumpur Radar at 1646:39 UTC [0046:39 MYT].

At 1646:58 UTC [0046:58 MYT], MH370 was cleared to climb to FL250 and subsequently to FL350 at 1650:08 UTC [0050:08 MYT]. MH370 reported maintaining FL350 at 1701:17 UTC [0101:17 MYT] and reported maintaining FL350 again at 1707:56 UTC [0107:56 MYT].

At 1719:26 UTC [0119:26 MYT], MH370 was instructed to contact HCM ACC on the radio frequency 120.9 MHz.

At 1719:30 UTC [0119:30 MYT], MH370 acknowledged with "*Good night Malaysian Three Seven Zero*". This was the last recorded radio transmission from MH370.

Radar recording showed that MH370 passed through waypoint IGARI at 1720:31 UTC [0120:31 MYT].

Based on the reconstruction of the flight profile conducted on the B777 simulator, the flight would be at waypoint IGARI one minute earlier than the original ETA of 1722 UTC [0122 MYT].

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[2] Waypoint - A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation. Waypoints are identified as either:

- *Fly-by waypoint - A waypoint which requires turn anticipation to allow tangential interception of the next segment of a route or procedure, or*
- *Flyover waypoint - A waypoint at which a turn is initiated in order to join the next segment of a route or procedure.*

The Mode S symbol of MH370 dropped off from radar display at 1720:36 UTC [0120:36 MYT], and the last secondary radar position symbol of MH370 was recorded at 1721:13 UTC [0121:13 MYT].

The disappearance of the radar position symbol of MH370 was captured by the KL ACC radar at 1721:13 UTC [0121:13 MYT]. The Malaysian military radar and radar sources from two other countries, namely Viet Nam and Thailand, also captured the disappearance of the radar position symbol of MH370. The Bangkok radar target drop occurred at 1721:13 UTC [0121:13 MYT] and Viet Nam's at 1720:59 UTC [0120:59 MYT].

The last Aircraft Communication Addressing and Reporting System (ACARS) (refer to *Section 1.9.4 - ACARS*) transmission was made through the aircraft's satellite communication system at 1707:29 UTC [0107:29 MYT].

Figure 1.1A (below) shows the *Chronological Sequence of Events of the Disappearance of MH370 (in pictorial form and not to scale)*

1.1.2 Actions by HCM ACC and KL ACC

At 1739:06 UTC [0139:06 MYT] HCM ACC queried KL ACC on the whereabouts of MH370. KL ACC contacted MAS ODC to check on the whereabouts of MH370.

HCM ACC had also contacted Hong Kong (China) ACC and Phnom Penh (Cambodia) ACC in an attempt to establish the location of MH370. However, no contact had been established by any of the ATC units.

Kuala Lumpur Aeronautical Rescue Coordination Centre (KL ARCC) was activated at 2130 UTC [0530 MYT]. There is no evidence to show HCM ACC activated its Rescue Coordination Centre.

1.1.3 Diversion from Filed Flight Plan Route

1) Malaysian Military Radar

The Military radar data provided more extensive details of what was termed as "Air Turn Back". It became very apparent, however, that the recorded altitude and speed change "blip" to "blip" were well beyond the capability of the aircraft. It was highlighted to the Team that the altitude and speed extracted from the data are subjected to inherent error. The only useful information obtained from the Military radar was the latitude and longitude position of the aircraft as this data is reasonably accurate.

At 1721:13 UTC [0121:13 MYT] the Military radar showed the radar return of MH370 turning right but shortly after, making a constant left turn to heading of 273°, flying parallel to Airway M765 to VKB (Kota Bharu).

Between 1724:57 UTC [0124; 57 MYT] to 1737:35 UTC [0137:35 MYT] the "blip" (a spot of light on a radar screen indicating the position of a detected aircraft) made heading changes that varied between 8° and 20°, and a ground speed that varied from 451 kt to 529 kt. The Military data also recorded a significant height variation from 31,150 to 39,116 ft.

The Military data further identified the "blip" on a heading of 239° at 1737:59 UTC [0137:59 MYT] parallel to Airway B219 towards VPG (VOR Penang). Heading of this "blip" varied from 239° to 255° at a speed from 532 to 571 kt. The height of this "blip" was recorded between 24,450 ft and 47,500 ft.

At 1752:31 UTC [0152:31 MYT] the "blip" was observed to be at 10 nm south of Penang Island on a heading of 261°, speed of 525 kt and at a height of 44,700 ft.

At 1801:59 UTC [0201:59 MYT] the data showed the "blip" on a heading of 022°, speed of 492 kt and altitude at 4,800 ft. This is supported by the "blip" detected by Military radar in the area of Pulau Perak at altitude 4,800 ft at 1801:59 UTC [0201:59 MYT]. At 1803:09 UTC [0203:09 MYT] the "blip" disappeared, only to reappear at 1815:25 UTC [0215:25 MYT] until 1822:12 UTC [0222:12 MYT], about 195 nm from Butterworth, on a heading of 285°, speed of 516 kt and at an altitude of 29,500 ft.

9	At 1721:13 UTC [0121:13 MYT], 3.2 nm after passing IGARI, the radar position symbol of MH370 dropped off
8	MH370 Mode S symbol dropped off at 1720:36 UTC [0120:36 MYT]
7	MH370 over waypoint IGARI at 1720:31 UTC [0120:31 MYT]
6	At 1719:26 UTC [0119:26 MYT], 8.6 nm to waypoint IGARI, KL ACC instructed MH370 to contact HCM ACC MH370 acknowledged with '*Good night Malaysian Three Seven Zero*' at 1719:30 UTC [0119:30 MYT]
5	MH370 maintaining FL350 at 1701:17 UTC [0101:17 MYT] MH370 reported again maintaining FL350 at 1707:56 UTC [0107:56 MYT]
4	MH370 climbing to FL350 at 1650:11 UTC [0050:11 MYT]
3	MH370 climbing to FL250 at 1647:03 UTC [0047:03 MYT]
2	MH370 climbing to FL180 at 1643:01 UTC [0043:01 MYT]
1	Lumpur Tower cleared for take-off at 1640:37 UTC [0040:37 MYT] and MH370 departed at 1642 UTC [0042 MYT]

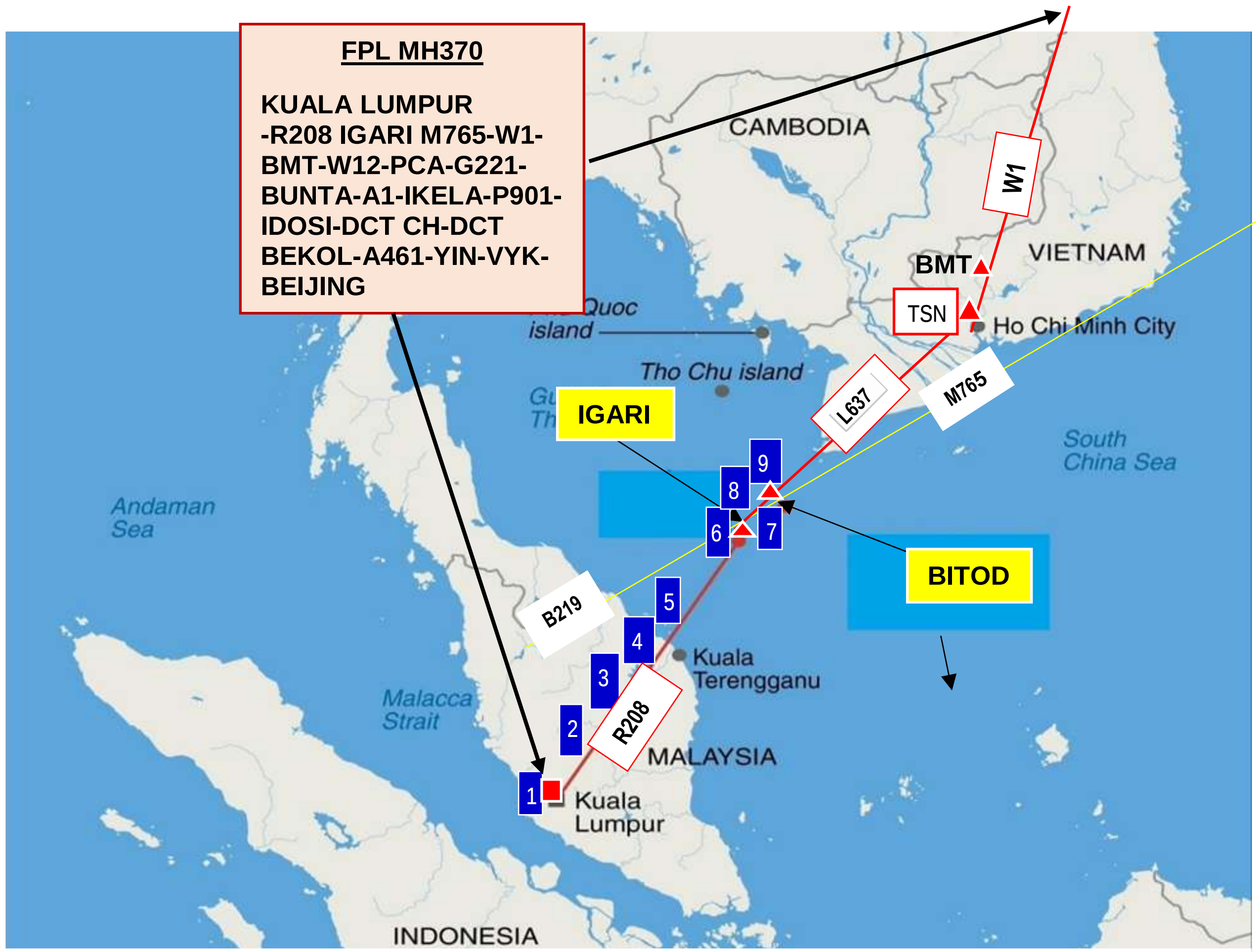


Figure 1.1A - Chronological Sequence of Events of Disappearance of MH370 (in pictorial form and not to scale)

Figure 1.1A – Chronological Sequence of Events of Disappearance of MH370 (in pictorial form and not to scale)

The tracking by the Military continued as the "blip" was observed to be heading towards waypoint MEKAR on Airway N571 when it finally disappeared at 1822:12 UTC [0222:12 MYT], 10 nm after waypoint MEKAR.

On the day of the disappearance of MH370, the Military radar system recognised the 'blip' that appeared west after the left turn over IGARI was that of MH370. Even with the loss of SSR data, the Military long range air defence radar with Primary Surveillance Radar (PSR) capabilities affirmed that it was MH370 based on its track behaviour, characteristics and constant/continuous track pattern/trend. Therefore, the Military did not pursue to intercept the aircraft since it was 'friendly' and did not pose any threat to national airspace security, integrity and sovereignty.

Based on the Malaysian Military data, a reconstruction of the profile was conducted on a Boeing 777 simulator. *Figure 1.1B* (below) in chart form shows the *Profile Chart of Data from Malaysian Military Radar.* Some of the speed and height variations were not achievable even after repeated simulator sessions.

It was also noted that, in the absence of autopilot or continuous manual control, an aircraft is very unlikely to maintain straight and level flight. Further, it is extremely unlikely for an aircraft to enter and maintain a turn and then return to straight and level flight for any significant period of time.

2) DCA Civilian Radar Data from Kota Bharu - Sultan Ismail Petra Airport Runway

The aircraft diversion from the filed flight plan route was recorded on the DCA radar playback:

a) From 1730:37 UTC [0130:37 MYT] to 1744:52 UTC [0144:52 MYT] a primary aircraft target was captured by the Terminal Primary Approach Radar located to the south of the Kota Bharu – Sultan Ismail Petra Airport runway.

b) The appearance of an aircraft target on the KL ACC radar display, coded as P3362, was recorded at 1730:37 UTC [0130:37 MYT] but the aircraft target disappeared from the radar display at 1737:22 UTC [0137:22 MYT].

c) At 1738:56 UTC [0138:56 MYT] an aircraft target, coded as P3401, appeared on the KL ACC radar display and disappeared at 1744:52 UTC [0144:52 MYT].

d) At 1747:02 UTC [0147:02 MYT] an aircraft target, coded as P3415, appeared on the KL ACC radar display but disappeared at 1748:39 UTC [0148:39 MYT], which appeared to be the continuity of the same target.

e) At 1751:45 UTC [0151:45 MYT] an aircraft target, coded as P3426, appeared on the KL ACC radar display but disappeared at 1752:35 UTC [0152:35 MYT].

Figure 1.1C (below) shows *Diversion from Filed Flight Plan Route (in pictorial form and not to scale).*

It has been confirmed by DCA and its radar maintenance contractor, Advanced Air Traffic Systems (M) Sdn. Bhd. (AAT), that it was the 60 nm Terminal Primary Approach Radar, co-mounted with 200 nm monopulse SSR[3] located to the south of Kota Bharu - Sultan Ismail Petra Airport runway, which captured the above-mentioned primary aircraft targets.

[3] *SSR (Secondary Surveillance Radar) - A surveillance radar system which uses transmitters/receivers system (interrogators) and transponders*.

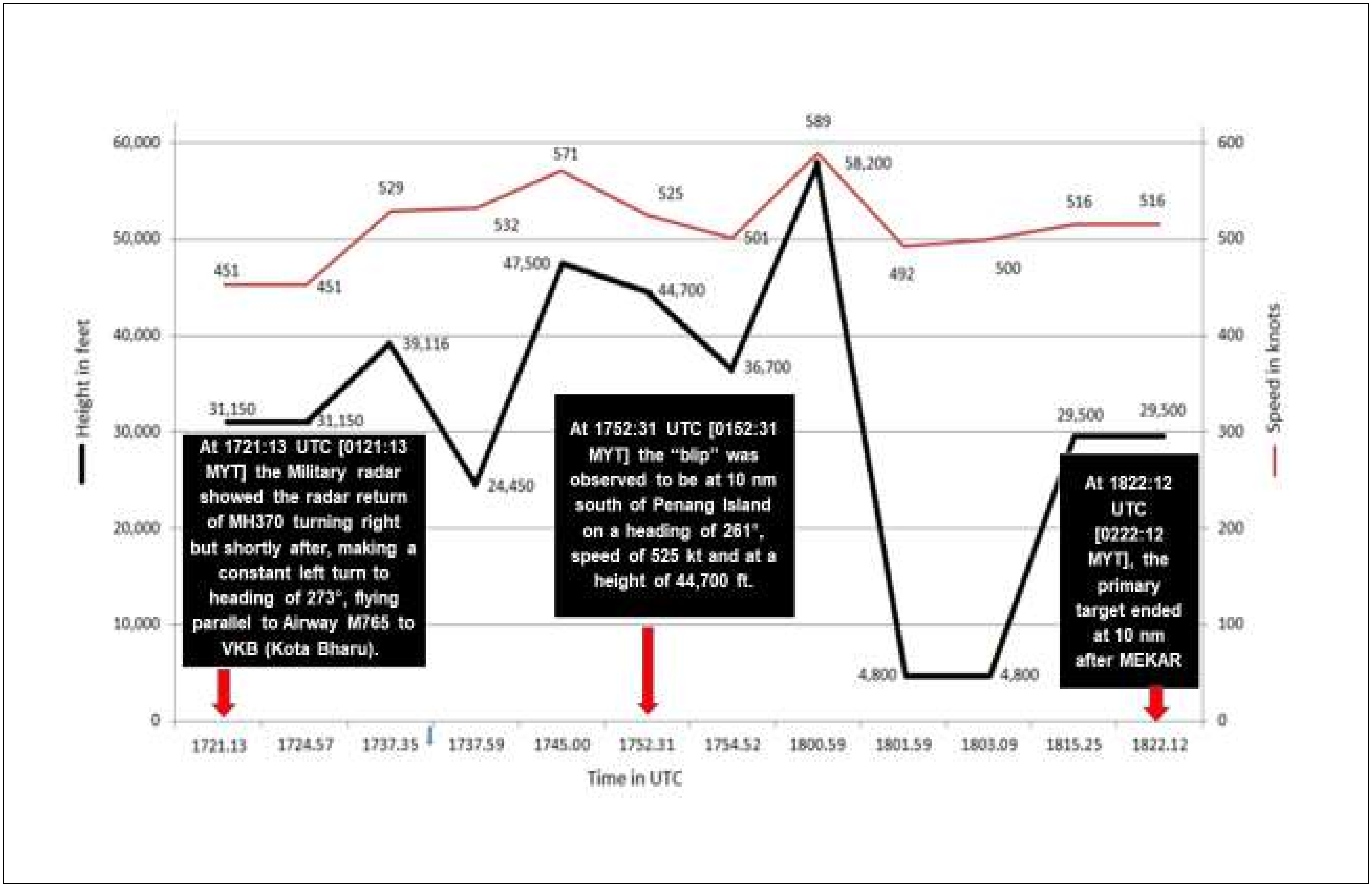
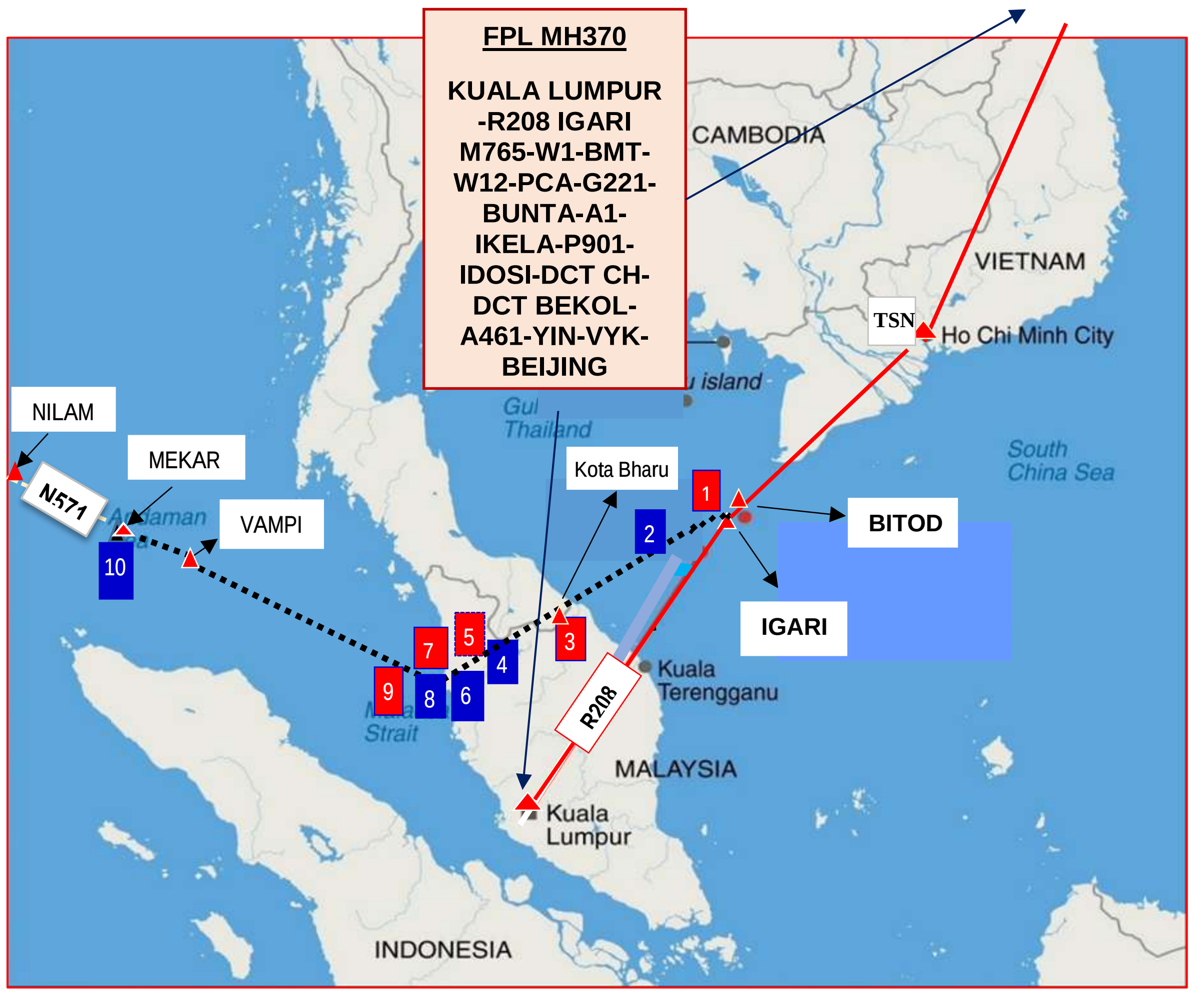


Figure 1.1B - Profile Chart of Data from Malaysian Military Radar (not to scale).

1	P3362: Appeared at 1730:37 UTC [0130:37 MYT]
2	P3362: Coasted at 1737:12 UTC [0137:12 MYT] Dropped at 1737:22 UTC [0137:22 MYT]
3	P3401: Appeared at 1738:56 UTC [0138:56 MYT]
4	P3401: Coasted at 1744:42 UTC [0144:42 MYT] Dropped at 1744:52 UTC [0144:52 MYT]
5	P3415: Appeared at 1747:02 UTC [0147:02 MYT]
6	P3415: Coasted at 1748:29 UTC [0148:29 MYT] Dropped at 1748:39 UTC [0148:39 MYT]
7	P3426: Appeared at 1751:45 UTC [0151:45 MYT]
8	P3426: Coasted at 1752:25 UTC [0152:25 MYT] Dropped at 1752:35 UTC [0152:35 MYT] P3426 last seen on radar display Approximately 6 nm south of Penang
9	The primary target (military radar) appeared to track west-northwest direction joining RNAV Route N571 at waypoint VAMPI thence to 10 nm north MEKAR *Source: RMAF*
10	The primary target ended at 10 nm after MEKAR at 1822:12 UTC [0222:12 MYT] *Source: RMAF*



	Filed Flight Plan Route
	Diversion route
	Radar target appearance
	Radar target coasted/dropped off

Figure 1.1C - Diversion from Filed Flight Plan Route - Civilian Radar (in pictorial form and not to scale)

Figure 1.1D (below) shows the suitable airports for emergency en-route diversion.

Figure 1.1D - Airports for Emergency Landing along the Flightpath of MH370 (chart not to scale)

Figure 1.1E (below) shows the *Filed Flight Plan message of MH370*.

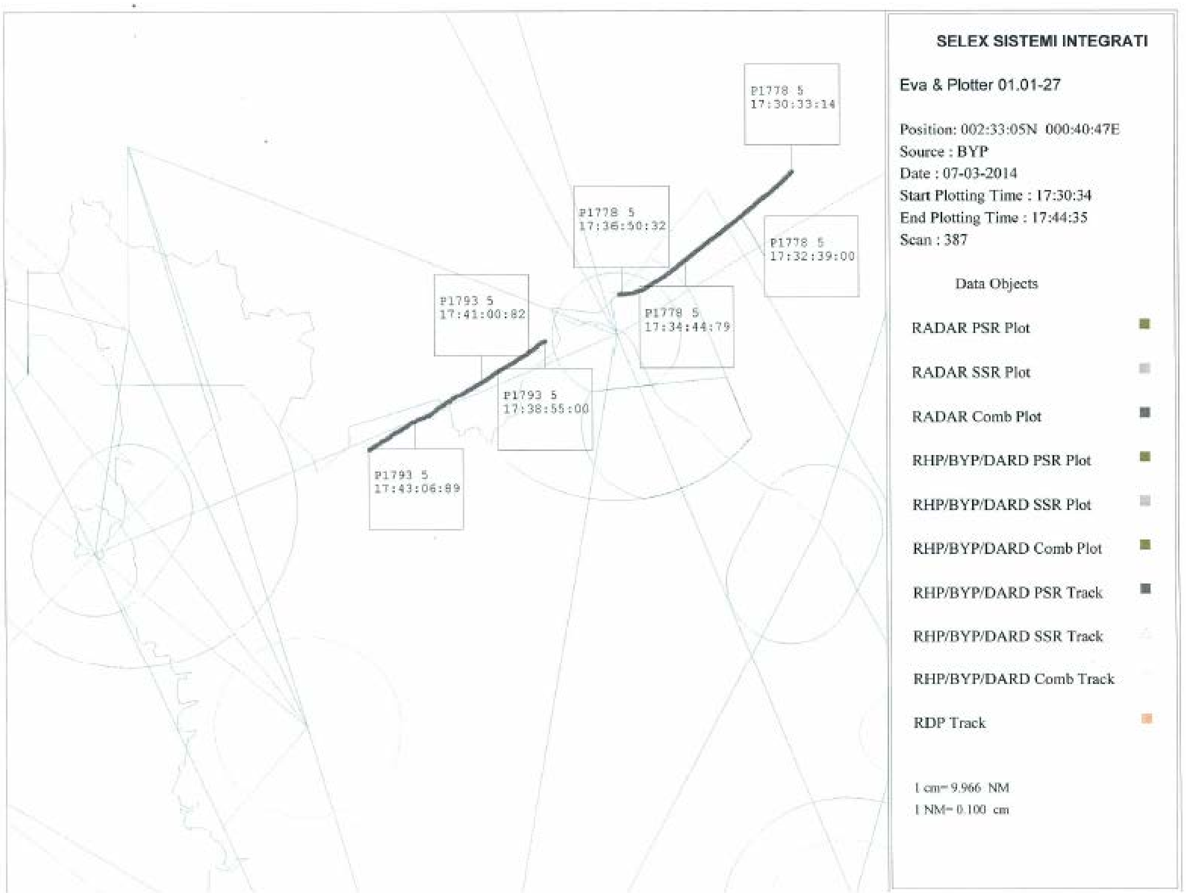
```
KLA297 070444
FF WMKKZQZX WMKKZRZX
070441 WMKKYOYX
(FPL-MAS370-IS
-B772/H-SDFGHIJ3J5M1RWXY/LB1D1
-WMKK1635
-N0470F290 DCT PIBOS R208 IKUKO/M081F330 R208 IGARI M765
 BITOD/N0480F330 L637 TSN/N0480F350 W1 BMT W12 PCA G221
 BUNTA/N0480F370 A1 IKELA/N0480F370 P901 IDOSI/N0480F390 DCT CH
 DCT BEKOL/K0900S1160 A461 YIN/K0890S1130 A461 VYK
-ZBAA0534 ZBTJ ZBSJ
-PBN/A1B1C1D1L1O1S2 DOF/140307 REG/9MMRO EET/WSJC0032 VVTS0042

ZJSA0210 VHHK0233 ZGZU0304 ZHWH0356 ZPE0450 SEL/QRC RMK/ACASII
EQUIPPED)
```

Source: DCA Malaysia

Figure 1.1E - Filed Flight Plan message of MH370.

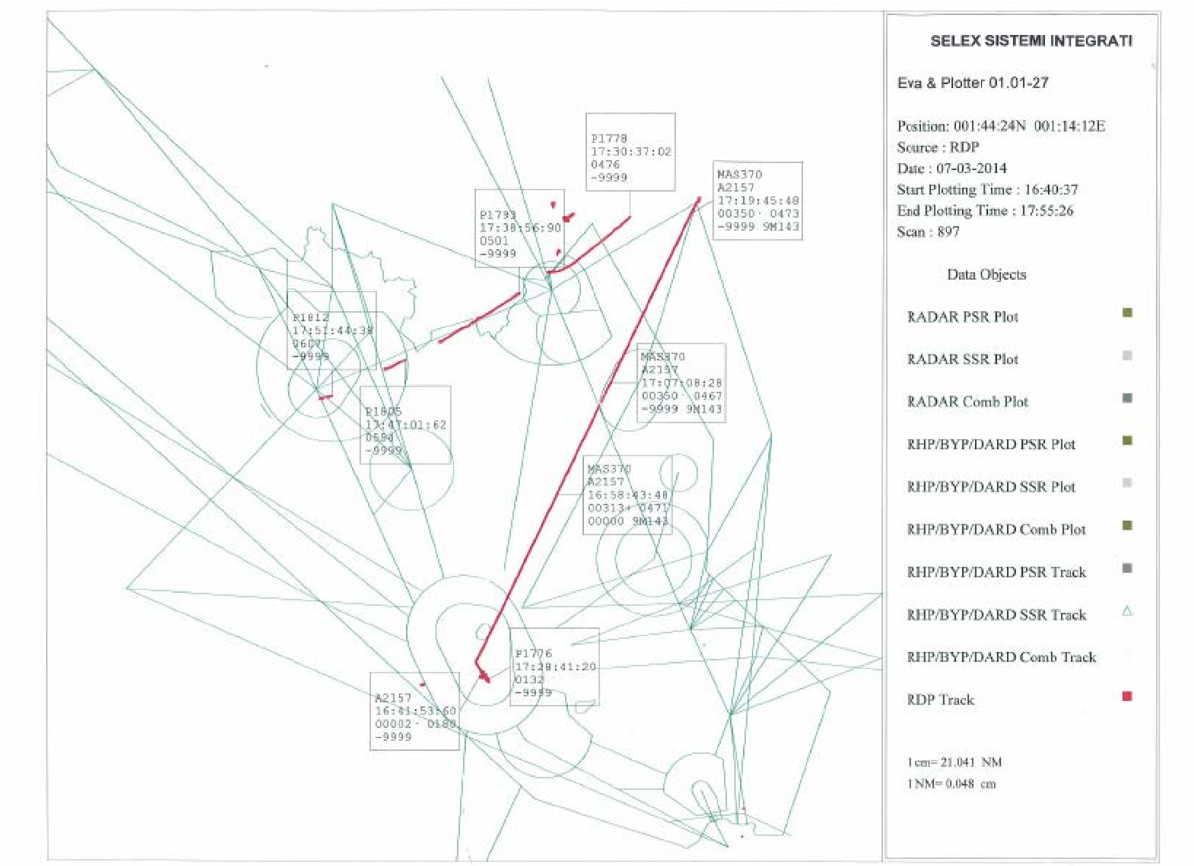
Figure 1.1F (below) shows Radar Data Plots (RDP) Tracks from the 60 nm Terminal Primary Approach Radar co-mounted with 200 nm monopulse SSR located to the south of Kota Bharu - Sultan Ismail Petra Airport runway after Diversion and *Figure 1.1G* (below) shows RDP Tracks from Kuala Lumpur after take-off.

All the primary aircraft targets that were recorded by the DCA radar are consistent with those of the military data that were made available to the Investigation Team.



Source: Advanced Air Traffic Systems (M) Sdn. Bhd. (AAT)

Figure 1.1F - Radar Data Plots (RDP) Tracks from the 60 nm Terminal Primary Approach Radar co-mounted with 200 nm monopulse SSR located to the south of Kota Bharu - Sultan Ismail Petra Airport runway after Diversion.



Source: Advanced Air Traffic Systems (M) Sdn. Bhd. (AAT)

Figure 1.1G - Radar Data Plots (RDP) Tracks from Kuala Lumpur after take-off

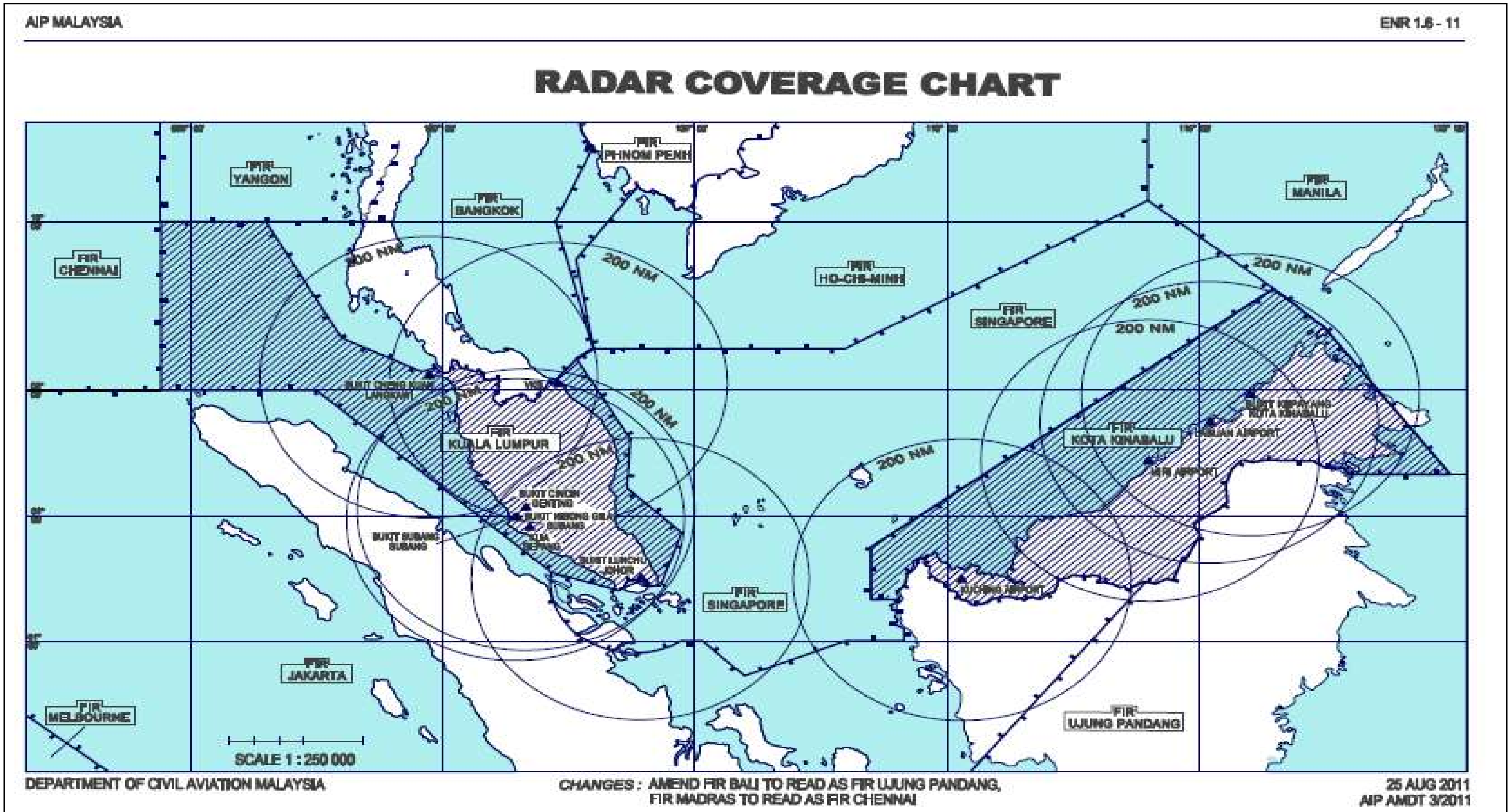
<u>Reference</u>:

The Malaysia Aeronautical Information Publication [AIP] ENR 1.6 dated 05 June 2008, AIP AMDT 2/2008 on the Provision of Radar Services and Procedures states that, in paragraph 1.1.4:

"*In the Kuala Lumpur and Kota Kinabalu FIRs, radar services are provided using the following civil/military ATC Radars:*

g) A 60 nm Terminal Primary Approach Radar co-mounted with 200 nm monopulse SSR located to the south of Kota Bharu - Sultan Ismail Petra Airport runway.".

Figure 1.1H (below) shows the Radar Coverage Chart of Kuala Lumpur and Kota Kinabalu FIRs.



Source: DCA Malaysia

Figure 1.1H - Radar Coverage Chart of Kuala Lumpur and Kota Kinabalu Flight Information Regions

3) Ho Chi Minh Air Traffic Services

The tracking of MH370 was captured by HCM ACC Secondary Radar at Tan Son Nhut and at Camau Province, and Automatic Dependent Surveillance- Broadcast (ADS-B) located at Conson Island/range 270 nm) at 1711:59 UTC [0111:59 MYT] as it was heading for waypoint IGARI.

At 1720:59 UTC [0120:45 MYT] the "blip" from MH370 from both SSR and ADS-B radar position symbols disappeared from the radar display.

A visit was made to the office of the Vietnamese Civil Aviation Authority (CAAV) in Ho Chi Minh City on 10 September 2014. In interviews, the Duty HCM Duty ACC Controller who was handling MH370 on that night could not explain why he did not initiate any call to MH370 within the standard 5 minutes as specified in the Letter of Agreement (LOA) between Department of Civil Aviation Malaysia and Viet Nam Air Traffic Management dated 07 July 2001 and effective on 01 November 2001 (Refer *Appendix 1.1A - Letter of Agreement between DCA Malaysia and Viet Nam*). It was noted that he had only initiated an enquiry on the whereabouts of MH370 at 1739:03 UTC [0139:03 MYT] after a lapse of 12 minutes.

The Duty Controller however had stated that he had initiated calls to other aircraft on the existing frequency and on the emergency frequency of 121.5 MHz. This was neither supported nor collaborated by any documents.

The landline recorded transcripts between KL ACC and HCM ACC suggested that there were confusions on the position of MH370. This was evident when HCM ACC requested KL ACC for information on MH370 at 1739:06 UTC [0139:06 MYT]. This conversation took place:

KL ACC: *"MH370 already transferred to you rite?"*

HCM ACC: *"Yeah…yeah…I know at time two zero but we have no just about in contact up to BITOD…we have radar lost with him…the one we have to track identified via radar*."

When pointed out that neither HCM ACC SSR nor ADS-B showed any presence of a "blip" of MH370, the Duty Controller could not explain why he mentioned BITOD.

MH370 was operating within the Singapore FIR, in that portion of the airspace which has been delegated to Malaysia (Refer to *Figure 2.2K - Singapore Airspace delegated to Malaysia)* for the provision of air traffic services when the last air-ground radio contact was made at 1719 UTC [0119 MYT]. As such, KL ACC should be responsible for the alerting service which would mean that KL ACC would have to declare the Distress Phase at 1827 UTC [0227 MYT] when HCM ACC informed that there had been no two-way radio communications with MH37O.

The *DETRESFA* was only declared at 2232 UTC [0632 MYT]. Refer to para. 2.2.7 Table 2.2C, No. 26-28 - Chronology of ATC Events following the Disappearance of MH370; and to para. 2.2.8 1) o) - Activation of Aeronautical Rescue Coordination Centre, for details.

Reference:

Manual of Air Traffic Services, Part 9 - Emergencies, para. 9-6-5, Para, 6.7.2 dated 15/3/2009 states:

> *If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegate to the Kuala Lumpur and Kota Kinabalu ATSCs and the position of the aircraft is in doubt, the responsibility for co-ordinating such service shall normally rest with the ATSC of the respective FIRs:*
>
> - *within which the aircraft was flying at the time of last air-ground radio contact;*
> - *that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;*
> - *within which the aircraft's intermediate stop or final destination point is located:*
>
>   *1) if the aircraft was not equipped with suitable two-way radio communication, or*
>
>   *2) was not under obligations to transmit position reports.*

and

ICAO Doc 4444 ATM/501 Procedures for Air Navigation - Air Traffic Management (PANS-ATM), page 9-6, para 9.2.2.2, dated 22/11/07 states:

> *When alerting services is required in respect of a flight operated through more than one FIR or control area, and when the position of the aircraft is in doubt, responsibility for coordinating such service*

shall rest with the ATS unit of the FIR or control area within which the aircraft was flying at the time of last air-ground radio contact:

a) that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;

b) within which the aircraft's intermediate stop or final destination point is located:

1) if the aircraft was not equipped with suitable two-way radio communication, or

2) was not under obligations to transmit position reports.

Based on interviews, HCM ACC had stated that it did not initiate any emergency actions as it did not receive any change of the transfer of control time of IGARI, MH370 did not contact the Centre at the stated time, and it was unable to establish radio communication with MH370.

MH370 was also operating in the airspace delegated to KL ACC and the last air-ground radio contact was with KL ACC. Hence the provision of alerting service for MH370 rests with KL ACC.

These uncertainties were further compounded by the Duty Despatcher, based on MAS Flight Following System (FFS), who mentioned that the aircraft was over the Cambodian airspace when in fact the filed flight plan routing did not include flying over the Cambodian airspace.

Added to these confusions, for reasons best known to him, the MAS Captain from the Technical and Development Department, Flight Operations spoke to KL ACC saying that the aircraft did not leave the Malaysian airspace. When interviewed, the Captain insisted that he was asking a question rather than making a statement. This conversation was recorded at 0521.23 MYT:

KL ACC: *"…had never leave Lumpur airspace?"*

MAS Captain: *"…yea he has not left Lumpur airspace because he has failed to call Ho Chi Minh."*

4) Kuala Lumpur ACC Radar

KL ACC Radar captured the disappearance of MH370 at 1721:13 UTC [0121:13 MYT]. In interviews with the Duty KL ACC Radar Controller, he stated that he did not notice the "blip" disappearance as MH370 was out of radar coverage and would be in contact with HCM ACC after the transfer of responsibility was effected.

From 1730:37 UTC [0130:37 MYT] to 1752:35 UTC [0152:35 MYT], what appeared to be MH370 was captured on KL ACC primary radar, coded as P3362, P3401, P1415, P3415 and P3426 (P signifies Primary Radar). *Figure 1.1C - Diversion from Filed Flight Plan Route.*

The appearance of a "blip" coded as P3362 was recorded at 1730:37 UTC [0130:37 MYT)] but disappeared abruptly at 1737:22 UTC [0137:22 MYT].

At 1738:56 UTC [0138:56 MYT], a "blip" identified as P3401 was tracked by KL ACC but disappeared at 1744:52 UTC [0144:52 MYT].

Shortly after, another "blip" coded as P3451 appeared at 1747.02 UTC [0147:02 MYT] but disappeared at 1748:39 UTC [0148:39 MYT].

At 1751:45 UTC [0151:45 MYT], a "blip" coded as P3426 appeared south of Penang Island but disappeared at 1752:35 UTC [0152:35 MYT].

5) Medan Air Traffic Control Radar

The Medan ATC Radar has a range of 240 nm, but for unknown reasons, did not pick up any radar return bearing the SSR transponder code A2157 of MH370.

The Indonesian Military however stated that they picked up MH370 earlier as it was heading towards waypoint IGARI.

No other information was made available.

6) Bangkok Air Traffic Control Radar

The radar position symbol with SSR transponder code A2157 was detected on the Aeronautical Radio of Thailand Limited (AEROTHAI) radar display at 1711 UTC [0111 MYT] as the aircraft was tracking for waypoint IGARI.

Thailand DCA is a government agency whereas AEROTHAI is a state enterprise under the Ministry of Transport and Communications. AEROTHAI is the air navigation service provider responsible for the provision of Air Traffic Services within the Bangkok Flight Information Region (FIR).

As the flight plan of MH370 did not fall under the purview of Thailand's FIR, Bangkok ACC did not pay attention to this flight. On playback of the radar recording it was noted that the radar position symbol of A2157 disappeared at 1721:13 UTC [0121:13 MYT].

7) Singapore Air Traffic Services

The Team visited Singapore to conduct interviews with officers from Civil Aviation Authority of Singapore (CAAS) and the Air Traffic Controllers on duty on 07 March 2014. The following were noted:

i) Singapore ACC did not have radar coverage over the South China Sea. (*ADS and CPDLC services are available to suitably equipped aircraft operating outside radar cover over the South China Sea …);*

Reference:

AIP Singapore page 94 GEN 3.4-2, 10 MAR 11, para 3.2.2 d.

ii) At 2104:00 UTC [0504:00 MYT], Singapore ACC received a call from Hong Kong ACC enquiring any knowledge of a missing Malaysian aircraft MH370. Hong Kong ACC then requested assistance from Singapore ACC to contact Lumpur ACC for detailed information. It was evident that Singapore ACC was not aware of the problem until this call was received. Hong Kong ACC however had the knowledge of the missing Aircraft earlier after receiving unconfirmed information from HCM ACC;

iii) At 2109:13 UTC [0509:13 MYT], Singapore ACC contacted Lumpur ACC to relay the query from Hong Kong ACC.

Reference

Radiotelephony transcripts between Sin*gapore ACC and KL ACC Sector 3+5 Planner - Appendix 1.18G* on *Direct Line Coordination Communication,* pages 109 to 114*.*

1.1.4 Role of Malaysian Military

On the day of the disappearance of MH370, the Military radar system recognised the 'blip' that appeared west after the left turn over IGARI was that of MH370. Even with the loss of SSR data, the Military long range air defence radar with Primary Surveillance Radar (PSR) capabilities affirmed that it was MH370 based on its track behaviour, characteristics and constant/

continuous track pattern/trend. Therefore, the Military did not pursue to intercept the aircraft since it was 'friendly' and did not pose any threat to national airspace security, integrity and sovereignty.

1.1.5 Detection of Hand Phone Signal

A Telco service provider in an interview with the RMP confirmed a signal "hit" occurred at 0152:27 MYT on 08 March 2014, coming from the mobile phone tower (LBS Location Base station) at Bandar Baru Farlim Penang. The signal "hit" however did not record any communication except to confirm that it was in the ON mode signal related to the "hit". The phone number *xxxxxxx* was later traced to that registered under the FO. This was supported by the RMP's report.

To ascertain the probability of making calls inside an aircraft from different altitudes, a reconstructed flight using a King Air 350 over the said area and during the same time when the signal "hit" happened was carried out shortly after the disappearance of MH370. The flight was conducted from an altitude of 24,000 ft with step descents every 4,000 ft until 8,000 ft. The next descent was to 5,000 ft but at 1,000 ft interval. An expert from a Telco service provider conducted the test using three different brands of phone and related equipment that were carried on board the King Air 350. Test call will be automatically answered by the server in the event of connectivity.

In summary, during the tests, it was found that it was difficult to maintain successful call connectivity above 8,000 ft. However, one brand of phone was able to make a call at 20,000 ft. Only one cell phone service provider recorded the highest call attempts using their 3G network above 8,000 ft. Two service providers could only provide connection below 8,000 ft.

The Telco service provider expert cautioned the Team that the tests would be difficult to conclude and use as scientific/theoretical assumptions for the case of MH370, as the measurement results were only valid for that specific time, flight path, speed, altitude, devices used, and environment during the tests.

1.1.6 Search for Aircraft

Extensive work done by the MH370 Search Strategy Group, coordinated by the Australian Transport Safety Bureau (ATSB), by analysing signals transmitted by the aircraft's satellite communications terminal to Inmarsat's Indian Ocean Region satellite indicated that the aircraft continued to fly for

several hours after loss of contact. The analysis showed the aircraft changed course shortly after it passed the northern tip of Sumatra (Indonesia) and travelled in a southerly direction until it ran out of fuel in the southern Indian Ocean west of Australia. Details of this work can be found in the ATSB's report: AE-2014-054 dated 26 June 2014, and in subsequent updates, available at ATSB's website:
http://www.atsb.gov.au/publications/investigation_reports/2014/aair/ae-2014-054/

On 03 October 2017, the ATSB published a report detailing the history of the search and made conclusions and recommendations relating to the search activities. This is contained in the report titled "***The Operational Search for MH370".*** The report and relevant attachments are available at ATSB's website:
https://www.atsb.gov.au/newsroom/news-items/2017/chapter-closes-on-mh370/

The search for Malaysia Airlines flight MH370 commenced on 8 March 2014 and continued for 1,046 days until 17 January 2017 when it was suspended in accordance with a decision made by the Governments of Malaysia, Australia and the People's Republic of China. This involved surface searches in the South China Sea, Straits of Malacca and the southern Indian Ocean. The 52 days of the surface search involving aircraft and surface vessels covered an area of several million square kilometres. A sub surface search for the aircraft's underwater locator beacons was also conducted during the surface search. The underwater search started with a bathymetry survey which mapped a total of 710,000 square kilometres of Indian Ocean seafloor and continued with a high-resolution sonar search which covered an area in excess of 120,000 square kilometres. The last search vessel left the underwater search area on 17 January 2017 without locating the missing aircraft. Although combined scientific studies continued to refine areas of probability, there was no new information at that date to determine the specific location of the aircraft.

On 10 January 2018, the Malaysian Government entered into an agreement with the US company, Ocean Infinity, to conduct a 90-day underwater search in an area that was considered the most likely location for the wreckage. This search which commenced in the identified search area on 22 January 2018 was completed on 29 May 2018 without locating the missing aircraft. The search utilising the most advance underwater search technology currently available covered an area in excess of 112,000 square kilometres.

Details on the whole search effort for the aircraft have been documented elsewhere, in particular in the Australian Transport Safety Bureau report, "The Operational Search for MH370", in relation to the search in the southern Indian Ocean and the weekly updates provided by the MH370 Response Team in relation to the re-activated search by Ocean Infinity, and are separate and distinct from this Safety Investigation Report.

SECTION 1 – FACTUAL INFORMATION

1.2 INJURIES TO PERSONS

While injuries to persons on the flight could not be established as no survivors or bodies were found to date, the fact remains that there are 239 persons still missing.

SECTION 1 – FACTUAL INFORMATION

1.3 DAMAGE TO AIRCRAFT

Several pieces of debris were found washed ashore the south eastern coasts of Africa (South Africa, Mozambique and Tanzania), the Islands of Madagascar, Mauritius and Réunion, suggesting that the aircraft had suffered damage.

Refer to *Section 1.12 - Wreckage and Impact Information* for the list of significant debris possibly/confirmed belonging to MH370, recovered and examined to date.

SECTION 1 – FACTUAL INFORMATION

1.4 OTHER DAMAGES

Other damages could not be established as the main wreckage of the aircraft had not been found. There was no reported ground impact or damage to any ground facilities or properties.

SECTION 1 – FACTUAL INFORMATION

1.5 PERSONNEL INFORMATION

1.5.1 Introduction

This investigation emphasised on the Pilot-in-Command (PIC), First Officer (FO) and the 10 cabin crew but did not include the passengers on board Flight MH370. The factual information of the crew was gathered from the following sources:

1) **Personal records/files of the Pilot-in-Command, First Officer and the Cabin Crew from Malaysia Airlines**

   These documents included the log book, certificates, licences, medical records and any disciplinary/administrative actions;

2) **Investigation details from the Polis Di Raja Malaysia (Royal Malaysia Police)**

   These were statements obtained from the next-of-kin and relatives, doctors/ care givers, co-workers, friends and acquaintances; financial records of the flight crew; Closed Circuit Television (CCTV) recordings at KLIA; and analysis of the radio transmission made between MH370 and ground air traffic control;

3) **Medical records from private health care facilities and from the Malaysia Airlines Medical Centre; and**

4) **Interviews with Malaysia Airlines staff and several of the next-of-kin of the crew**

The facts obtained were in relation to the demographic and employment history, financial background and insurance cover, significant past medical and medication history, psychological, social and behavioural pattern of the crew.

1.5.2 Malaysia Airlines Training and Check Records

As professional pilots, the two Malaysia Airlines (MAS) flight crew were subjected to periodic checks when flying on the type of aircraft at least on a bi-annual basis to revalidate the currency of their licences. These performance checks were conducted in approved flight simulators and in addition, further checks are conducted on route flying duties on normal commercial flights on a yearly basis.

1.5.3 Pilot-in-Command

The PIC was born in the Island of Penang. He completed his Malaysian Certificate of Education (MCE) - the equivalent of the United Kingdom Ordinary (UK ‘O’) Level - at the Penang Free School, where he sat for his MCE Examination in 1978. In 1981 he was accepted as a Cadet Pilot with MAS under the sponsorship of Majlis Amanah Rakyat (MARA), a People’s Trust Council of the Malaysian Government.

1) Personal Profile of Pilot-in-Command

Sex	Male
Age	53 years
Marital Status	Married with 3 children
Date of joining MAS	15 June 1981
Licence country of issues	Malaysia
Licence type	Air Transport Pilot Licence (ATPL)
Licence number	A751
Validity Period of Licence	14 May 2014
Ratings	Boeing B777
Medical Certificate	First Class (valid until 30 June 2014)
Aeronautical experience	18423:40 hours
Experience on type	8659:40 hours
Last 24 hours	0:00:00 hours
Last 72 hours	07:00:00 hours
Last 07 days	20:39:00 hours
Last 28 days	91:04:00 hours
Last 90 days	303:09:00 hours
Last line check	08 April 2013
Instrument rating check	15 November 2013
Last proficiency	15 November 2013
Last promotion	B777 Captain (22 September 1998)

The PIC was sent to Manila in the Philippines to be provided ab-initio pilot training and graduated 2 years later with a Commercial Pilot Licence & Instrument Rating (CPL & IR). He joined MAS as a Second Officer in 1983 and was posted on the F27 where he obtained his initial airline flying experience. He was then posted to the B737-200 in 1985, thereafter the A300B4, and stayed on as First Officer (FO) until March 1990. In July 1990 he was promoted to captain and took his first command on the F50 aircraft.

By the end of 1991 he was promoted to Captain on the B737-400 until December 1996. His next promotion was to the A330-300 and stayed on the fleet until September 1998 when he was promoted to the B777-200ER fleet until the day of the event. By virtue of his good track record and seniority he was made a Type Rating Instructor (TRI) and Type Rating Examiner (TRE) on this present fleet effective November 2007.

The PIC's flying record for the last 72 hours and preceding 28 days' cycle were well within the Company's specified limits. His last flight as an operating PIC was to Denpasar, Bali, in the Republic of Indonesia on 03 March 2014. This was a daily return flight with a sector time of approximately 3 hours. On the day of the event, he was conducting training for the FO who was functionally checked out.

2) Royal Malaysia Police's Report on Flight Simulator of PIC

The Royal Malaysia Police (RMP) seized the PIC's home flight simulator from the residence of the PIC on 15 March 2014.

The RMP Forensic Report dated 19 May 2014 documented more than 2,700 coordinates retrieved from separate file fragments and most of them are default game coordinates.

It was also discovered that there were seven 'manually programmed' waypoint[4] coordinates (*Figure 1.5A* [below]), that when connected together, will create a flight path from KLIA to an area south of the Indian Ocean through the Andaman Sea. These coordinates were stored in the Volume Shadow Information (VSI) file dated 03 February 2014. The function of this file was to save information when a computer is left idle for more than 15 minutes. Hence, the RMP Forensic Report could not determine if the waypoints came from one or more files.

The RMP Forensic Report on the simulator also did not find any data that showed the aircraft was performing climb, attitude or heading manoeuvres, nor did they find any data that showed a similar route flown by MH370.

The RMP Forensic Report concluded that there were no unusual activities other than game-related flight simulations.

[4] 'Manually programmed waypoints' - Manually programmed waypoints are waypoints that are not published in Airway Charts

Figure 1.5A - Snapshot of Seven Manually Programmed 'Waypoints'

Source: Royal Malaysia Police

1.5.4 First Officer

The FO was born in the State of Kelantan and had his basic primary education in Segamat, Johor. He completed his secondary Education in Maktab Rendah Sains MARA (MRSM) or MARA Junior Science College, in Taiping, Perak, where he left in 2004 with the Sijil Pelajaran Malaysia (SPM) or Malaysia Certificate of Education, which is equivalent to the UK 'O' Level. He was accepted as a MAS Cadet Pilot and completed his flying training at the Langkawi Aerospace Training Centre, Langkawi in 2008.

His first fleet posting was on the B737-400 as a Second Officer until May 2010 He was promoted to FO in May 2010 and was on the fleet until August 2012. Between the end of 2012 to November 2013, he was promoted to the A330-300 and the B777-200.

On the day of the flight, he was operating his last training flight before he was scheduled to be checked out on his next scheduled flight. His flying record for the last 72 hours and preceding 28 days cycle were well within the Company's specified limits. His previous flight as a functional FO under Line Training, was to Frankfurt, Germany, on 01 March 2014 and he returned to Malaysia on 02 March 2014. All his required licences and certificates were valid when he was assigned to operate this flight to Beijing.

1) Personal Profile of First Officer

Sex	Male
Age	27 years
Marital Status	Single
Date of joining MAS	23 July 2007
Licence type	Air Transport Pilot Licence (ATPL)
Licence number	A3550
Validity Period of Licence	26 July 2014
Ratings	Boeing B777
Medical Certificate	First Class (valid until 31 October 2014)
Aeronautical experience	2813:42 hours
Experience on type	39:11 hours
Last 24 hours	0:00:00 hours
Last 72 hours	0:00:00 hours
Last 07 days	28:47:00 hours
Last 28 days	51:17:00 hours
Last 90 days	158:46:00 hours
Last line check*	22 July 2013 (A330)
Instrument rating check*	04 December 2012 (A330)
Last proficiency	26 January 2014
Last promotion	B777 FO (04 November 2013)

* *No record on B777*

1.5.5 Summary of Work Schedule for Flight Crew of MH370

A summary of the work schedule for the PIC and the FO, three months prior to the eventful flight, is available in *Table* 1.5A (below).

Rank	24	72	7	28	90	SEP Validity
	Hours		Days			
Pilot-in-Command	0:00:00	07:00:00	20:39:00	91:04:00	303:09:00	14 May 2014
First Officer	0:00:00	0:00:00	28:47:00	51:17:00	158:46:00	26 July 2014

Table 1.5A - 3 Months Work Schedule of PIC and FO

1.5.6 Cabin Crew and Personal Profiles

The cabin crews' flying experiences spread from 13 years for the most junior member to 35 years for the most senior member. A review of their records in MAS reveals that all certificates, which include Safety Emergency Procedures (SEP) training, Crew Resource Management (CRM), Safety Awareness Programme (SAP), are valid as per the requirement stated in the Company's document. CRM & SAP incorporate Human Factors as part of the training modules. The flying records which were monitored by the Scheduling Office indicated that all the cabin crew were well-rested before operating the flight.

1) In-flight Supervisor (IFS)

Sex	Male
Age	55 years
Marital status	Married with 4 children
Date of Joining MAS	19 November 1979
Aircraft Ratings	A330/B777/B747
Crew Performance Appraisal	Rating: 4
Validity period of licence	28 April 2014
Aeronautical experience	35 years
Medical History	43 days medical leave including 6 days hospitalisation in 2013
Last 24 hours	0:00:00 hours
Last 72 hours	8:00:00 hours
Last 07 days	19:44:00 hours
Last 28days	82:43:00 hours
Last 90 days	305:06:00 hours
Last promotion	IFS (27 March 2000)

2) Chief Steward (CS)

Sex	Male
Age	49 years
Marital status	Married with 2 children
Date of Joining MAS	13 November 1989
Aircraft Ratings	A330/B777/A380
Crew Performance Appraisal	Rating 4
Validity period of licence	26 June 2014
Aeronautical experience	25 years
Last 24 hours	0:00:00 hours
Last 72 hours	0:00:00 hours
Last 07 days	30:56:00 hours
Last 28 days	124:35:00 hours
Last 90 days	408:32:00 hours
Last promotion	CS (06 March 2000)

3) Chief Stewardess (CSS)

Sex	Female
Age	49 years
Marital status	Married with a child
Date of Joining MAS	02 January 1990
Aircraft Ratings	A330/B777/A380
Crew Performance Appraisal	Rating 5
Validity period of licence	23 October 2014
Aeronautical experience	24 years
Last 24 hours	0:00:00 hours
Last 72 hours	0:00:00 hours
Last 7 days	30:55:00 hours
Last 28 days	118:02:00 hours
Last 90 days	355:23:00 hours
Last promotion	CSS (22 October 2003)

4) Leading Steward (LS)

Sex	Male
Age	42 years
Marital status	Married with 4 children
Date of Joining MAS	05 October 1995
Aircraft Ratings	B737/B777/A380
Crew Performance Appraisal	Rating 4
Validity period of licence	22 August 2014
Aeronautical experience	19 years
Last 24 hours	00:00:00 hours
Last 72 hours	10:47:00 hours
Last 7 days	38:38:00 hours
Last 28 days	106:10:00 hours
Last 90 days	365:51:00 hours
Last promotion	LS (28 May 2005)

5) Leading Stewardess (LSS)

Sex	Female
Age	42 Years
Marital status	Married with 2 children
Date of Joining MAS	18 August 1992
Aircraft Ratings	B737/B777/A380
Crew Performance Appraisal	Rating 5
Validity period of licence	01 November2014
Aeronautical experience	22 years
Last 24 hours	0:00:00 hours
Last 72 hours	11:36:00 hours
Last 7 days	41:27:00 hours
Last 28 days	140:11:00 hours
Last 90 days	443:23:00 hours
Last promotion	LSS (09 May 2004)

6) Flight Stewardess (FSS) 1

Sex	Female
Age	42 years
Marital status	Married with 2 children
Date of Joining MAS	18 January 1992
Aircraft Ratings	A330/B777/A380
Crew Performance Appraisal	Rating 4
Validity period of licence	27 June 2014
Aeronautical experience	22 years
Last 24 hours	0:00:00 hours
Last 72 hours	9:39:00 hours
Last 7 days	34:22:00 hours
Last 28 days	93:50:00 hours
Last 90 days	327:18:00 hours
Last promotion	FSS wide-body aircraft (18 January 1993)

7) Flight Stewardess (FSS) 2

Sex	Female
Age	39 years
Marital status	Married with 2 children
Date of Joining MAS	16 April 1996
Aircraft Ratings	A330/B777/A380
Crew Performance Appraisal	Rating 4
Validity period of licence	11 May 2014
Aeronautical experience	18 years
Last 24 hours	0:00:00 hours
Last 72 hours	0:00:00 hours
Last 7 days	16:12:00 hours
Last 28 days	112:11:00 hours
Last 90 days	323:55:00 hours
Last promotion	FSS Wide-body aircraft (01 October 2001)

8) Flight Steward (FS) 1

Sex	Male
Age	46 years
Marital status	Married with 3 children
Date of Joining MAS	16 April 1996
Aircraft Ratings	B737/B777/A380
Crew Performance Appraisal	Rating 5
Validity period of licence	24 October 2014
Aeronautical experience	18 years
Last 24 hours	0:00:00 hours
Last 72 hours	11:02:00 hours
Last 7 days	30:58:00 hours
Last 28 days	119:27:00 hours
Last 90 days	429:15:00 hours
Last promotion	FS Wide-body aircraft (03 December 2001)

9) Flight Steward (FS) 2

Sex	Male
Age	41 years
Marital status	Married with 2 children
Date of Joining MAS	13 February 1997
Aircraft Ratings	B737/B777/A380
Crew Performance Appraisal	Rating 5
Validity period of licence	03 November 2014
Aeronautical experience	17 years
Last 24 hours	0:00:00 hours
Last 72 hours	0:00:00 hours
Last 7 days	30:36:00 hours
Last 28 days	122:22:00 hours
Last 90 days	391:20:00 hours
Last promotion	FS Wide-body aircraft (15 February 2002)

10) Flight Steward (FS) 3

Sex	Male
Age	34 years
Marital status	Married with 2 children
Date of Joining MAS	27 September 2001
Aircraft Ratings	B737/B777/A380
Crew Performance Appraisal	Rating 5
Validity period of licence	06 February 2015
Aeronautical experience	13 years
Last 24 hours	0:00:00 hours
Last 72 hours	10:47:00 hours
Last 7 days	26:24:00 hours
Last 28 days	125:01:00 hours
Last 90 days	435:43:00 hours

1.5.7 Disciplinary/Administrative Actions

There were no major disciplinary records on any of the flight and cabin crew. However, there were minor disciplinary issues among the cabin crew, where cautionary administrative letters were issued.

1.5.8 Financial Background and Insurance Cover

The PIC held bank accounts, two savings accounts, one current account, two national trust funds (ASB and ASN) and a joint account with his wife. He had a credit card. He was contributing to the Employees Provident Fund (EPF). There is no record of him having secured a life insurance policy. He had 2 houses, one in Shah Alam and the other in Subang Jaya. He had taken a bank loan on one of his houses and had a mortgage insurance policy on this loan. He also had 3 vehicles. His gross monthly income and out-of-pocket expenses indicated nothing unusual.

The PIC also had a trading account with an investment bank. The Central Depository System (CDS) and Trading accounts were opened since 13 February 1998 and 19 March 1998 respectively. The CDS account was inactive whereas the last transaction of the trading account was noted on 03 February 2000.

The FO had two saving accounts and a national trust fund (ASB) account. He contributed to the EPF. He owned two cars and spent money on the upkeep of his cars. He did not have much savings in his bank account. He had a life insurance policy and a mortgage insurance policy for a loan he took for his car.

The cabin crew had bank accounts and loans. However, the gross monthly income and out-of-pocket expenses indicated nothing unusual. There is also no evidence of recent or imminent significant financial transactions carried out.

1.5.9 Significant Past Medical and Medication History

The PIC had received treatment for minor medical ailments and was diagnosed as having osteoarthritis on 05 May 2007. He had a spinal injury on 28 January 2007 in a paragliding event. He sustained a fracture of the 2nd lumbar vertebra and underwent surgery on 30 January 2007 in a private health care facility. He was discharged on 05 February 2007 and went for a follow-up as advised. He was certified fit to fly in mid-2007 and went regularly for his six-monthly medical examinations for his continued licensure as a pilot. For his pain he was noted to have taken analgesics on an irregular basis. Based on available information, he was not on any regular long-term medication for any chronic medical illness.

There was no significant health-related issue for the FO. He went regularly for his yearly medical examinations for his continued licensure to fly.

Based on the medical records from MAS, there were no unusual health-related issues for the cabin crew, except for the in-flight supervisor who had a history of first onset of seizures on 09 June 2013. He was admitted on the same day in a private health care facility and was treated by a Consultant Neurologist. He was discharged on 14 June 2013 and went for a follow-up as advised. He had not experienced any further seizures since his discharge. He was certified fit to fly on 06 August 2013.

1.5.10 Psychological and Social Events

The PIC's ability to handle stress at work and home was reported to be good. There was no known history of apathy, anxiety, or irritability. There were no significant changes in his lifestyle, interpersonal conflict or family stresses.

Similarly, the FO's ability and professional approach to work was reported to be good. This was evident with the rapid fleet promotion within 3 years as a professional pilot. There were no reports on recent changes in his behaviour or lifestyle.

1.5.11 Behavioural Events

There were no behavioural signs of social isolation, change in habits or interest, self-neglect, drug or alcohol abuse of the PIC, FO and the cabin crew.

The CCTV recordings at KLIA on 07 March 2014 were evaluated to assess the behavioural pattern of the PIC, and the FO from the time of arrival at KLIA until boarding time.

Three previous CCTV recordings of the movements of the PIC in KLIA were also viewed to see the behavioural pattern and were compared with the CCTV recordings on 07 March 2014.

The PIC's movement was captured on CCTV at KLIA on the following days:

- 07 March 2014 - To Beijing

- 03 March 2014 - To Denpasar
- 26 February 2014 - To Melbourne
- 21 February 2014 - To Beijing

On studying the PIC's behavioural pattern on the CCTV recordings on the day of the flight and prior 3 flights there were no significant behavioural changes observed. On all the CCTV recordings the appearance was similar, i.e. well-groomed and attired. The gait, posture, facial expressions and mannerism were his normal characteristics.

The FO's movement captured on CCTV at KLIA on 07 March 2014 was observed. The FO's behavioural pattern on CCTV recordings on the day of the flight showed no significant behavioural changes.

1.5.12 Voice Recognition of the Radio Transmissions between MH370 and Air Traffic Control

The radio transmissions made between MH370 and the air traffic control were studied. The Team used pilot friends, family members, and an expert report of objective analysis of the radio transmissions in the voice recognition of the transmissions made between MH370 and air traffic control.

Five sets of audio recordings were analysed starting from Airway Clearance Delivery at 1625:52 UTC [0025:52 MYT] till the last utterance from Lumpur Radar at 1719:30 UTC [0119:30 MYT]. There was a total of 23 utterances as follows:

No.	Audio Recordings	Frequency (MHz)	Utterances	
1.	Airway Clearance Delivery (ACD)	126.0	→	4
2.	Lumpur Ground (LG)	122.27	→	6
3.	Lumpur Tower (LT)	118.8	→	4
4.	Approach Radar (AR)	121.25	→	3
5.	Lumpur Radar (LR)	132.5	→	6

From the information available, the first 3 sets of audio recordings (ACD, LG, LT), the speech segments are those of the FO before take-off, and the 4^{th} & 5^{th} (AR & LR) sets of the audio recordings originated from the PIC after take-off.

SECTION 1 – FACTUAL INFORMATION

1.6 AIRCRAFT INFORMATION

1.6.1 Airframe

Manufacturer	Boeing Company
Model	777-2H6ER
Serial Number	28420
Manufacturer's Line No.	404
Variable No.	WB175
Registration	9M-MRO
Date of manufacture	29 May 2002
Date of delivery to MAS	Delivered new on 31 May 2002
Certificate of Airworthiness	M.0938 valid to 02 June 2014
Certificate of registration	M.1124 issued 23 August 2006. Replacement of Certificate issued on 17 June 2002
Last Maintenance check	A1 Check on 23 February 2014 at 53,301:17 hours and 7,494 cycles
Total airframe hours/cycles	53,471.6 hours/7,526 cycles (as of 07 March 2014)

1.6.2 Engine

Manufacturer	Rolls-Royce
Model	RB211 Trent 892B-17
Engine 1 (Left)	
Serial Number	51463
Date of Construction	November 2004
Date Installed	08 May 2013
Last Shop Visit	06 September 2010 to 21 November 2010
Time in Service	40,779 hours, 5,574 cycles (as of 07 March 2014)
Engine 2 (Right)	
Serial Number	51462
Date of Construction	October 2004
Date Installed	15 June 2010
Last Shop Visit	05 February 2010 to 14 April 2010
Time in Service	40,046 hours, 5,508 cycles (as of 07 March 2014)

1.6.3 Auxiliary Power Unit

Manufacturer	Allied Signal
Model	GTCP 331-500B
Serial Number	P1196
APU Hours	22,093 (as of 07 March 2014)

1.6.4 Airworthiness and Maintenance

The aircraft, Serial Number 28420, was issued with a Federal Aviation Administration (FAA) Export Certificate of Airworthiness No: E370249 on 29 May 2002 and placed on the Malaysian aircraft register as 9M-MRO on 03 June 2002. Ownership of the aircraft, as stated on the Certification of Registration (C of R), was Malaysian Airline System Berhad. The ownership was subsequently changed to Aircraft Business Malaysia Sdn. Bhd., as the lessor, and leased and operated by MAS. A new C of R to reflect the new owner was issued on 17 June 2002.

A Certificate of Airworthiness (C of A) in the ‘PRIVATE’ category was initially issued on 03 June 2002. The aircraft was then flown to Kuala Lumpur, Malaysia where a C of A in ‘TRANSPORT PASSENGER’ category was issued by the DCA Malaysia on 12 June 2002 after the pre-service modifications were accomplished.

The C of A was subjected to annual renewal by DCA Malaysia and its renewal was subjected to compliance to the DCA Malaysia Airworthiness Notice No. 2 - Certificate of Airworthiness Renewal Procedure. The operator was required to declare the aircraft, engine, APU and equipment maintenance status as per the approved Maintenance Schedule, and that they complied with all the mandatory inspections and modifications originating from the State of Manufacture and State of Registry. The Quality Assurance Department of MAS was required to submit an ‘Aircraft Physical Inspection for the Purpose of C of A Issue/Renewal’ prior to the expiry of the C of A. An ‘Aircraft Survey Report for Certificate of Airworthiness’ will be issued by the DCA Inspector after a satisfactory physical inspection on the aircraft has been carried out. At times, the physical aircraft inspection has to coincide with the aircraft scheduled check at base or line maintenance.

The last C of A document review by DCA Inspector was carried out on 15 May 2013 for the C of A renewal and the aircraft physical inspection was carried out by MAS Quality Assurance Engineer (QAE) on 12 April 2013. The only inspection defect noted was a torn left hand flaperon inboard seal which was subsequently replaced. The aircraft C of A was renewed with no airworthiness issues identified.

1) Aircraft Maintenance Schedule

Brief description of the sections follows:

a) Section 1

The definition and introduction of the routine check types. Check intervals and limitations at which the maintenance tasks are to be carried out.

b) Section 2

Task Maintenance Requirements relating to on-wing tasks or tasks to be performed on parts after removal from the aircraft, their intervals and control in the routine maintenance check or independently.

c) Section 3

Component Maintenance Requirements on tasks to be performed on components, their intervals and controlled independently.

d) Section 4

Registers all the applicable job cards which are tied up to the maintenance Checks or Phases of inspections or tasks. The job cards/task cards cover the system, power plants, structural and zonal tasks.

The Master document of the approved Maintenance Schedule is stored in the Engineering Maintenance System (EMS) computer system bank and subject to regular revisions.

In addition to the Maintenance Schedule, a Supplementary Maintenance Schedule covered MAS' own generated tasks, non-mandatory manufacturer/vendor recommended tasks and non-airworthiness items.

The Maintenance check cycles are translated into the routine Transit Check, Stayover Check, Equalised 'A' Check, 'C' Check, 'C Extended' Check and 'D' Check. *Table 1.6A* (below) summarises the maintenance check intervals.

Transit	Stay-over	A Check	C Check	CX (Extended) Check	D Check
Whenever aircraft is on transit	6 hours planned or 12 hours unplanned	In 4 parts A1 thru A4 • A1 to A2 = 550 hours • A2 to A3 = 550 hours • A3 to A4 = 550 hours • A4 to A1 = 550 hours	In 2 parts C1 and C2 • C1 to C2 = 13 months • C2 to C1 = 13 months	52 months	8 years

Table 1.6A - Maintenance Check Intervals

No.	Type of Aircraft Checks	Date of aircraft Checks	Airframe Hours	Landing Cycles
1.	A1	23 February 2014	53,301:17	7,494
2.	A4	14 - 16 January 2014	52,785:37	7,422
3.	A3	13 December 2013	52,323:00	7,359
4.	A2	04 November 2013	51,766:29	7,282
5.	C1 and A1	29 August-26 September 2013	51,270:15	7,208
6.	A4	24 - 25 July 2013	50,810:19	7,132
7.	A3	19 June 2013	50,372:07	7,069
8.	A2	14 May 2013	49,840:28	6,994
9.	A1	04 April 2013	49,331:52	6,910
10.	A4	19 - 20 February 2013	48,836:23	6,840
11.	A3	10 January 2013	48,291:37	6,766
12.	A2	03 December 2012	47,749:39	6,693
13.	A1	25 October 2012	47,214:27	6,617
14.	A1, A4 and C2	06 - 22 July 2012	46,727:16	6,552
15.	A4, C2, CX and D	25 May - 26 June 2010	37,014:15	5,304

Table 1.6B - Recent Aircraft Checks

A review of the maintenance records for 9M-MRO revealed the following sequence of recent checks (*Table 1.6B* [above]) carried out by MAS prior to the disappearance of the aircraft on the 08 March 2014. No significant defects were noted during the checks including the turn-around transit checks.

The Maintenance Schedule incorporated the Structural Inspection Programme based on the B777 Maintenance Review Board Report and B777 Maintenance Planning Document, which are categorised as Structural Inspection Items, Corrosion Prevention and Control Items and Fatigue Related Inspection Items. Inspection findings would be evaluated by the MAS Reliability Section of the Technical Services Department and the department would recommend any follow-up actions as necessary and report to Boeing Company of all significant structural discrepancies.

The Maintenance Schedule also included compliance procedures for Airworthiness Directives[5], Airworthiness Limitations (AWL)[6] and Structural Inspections with Provisions for Damage Tolerance Rating. It also included Certification Maintenance Requirement Compliance to the Extended Twin Engine Operations (ETOPS)[7] operational approval, which was obtained from DCA Malaysia. The MAS B777 ETOPS Maintenance Manual specified the maintenance policies, procedures and requirements for ETOPS operations. A policy to prevent the same personnel to perform or certify certain tasks on multiple similar systems at the same downtime is stipulated. ETOPS task intervals cannot be exceeded. If a concession is given for a check that contains ETOPS task or for individual ETOPS task, the aircraft must be downgraded to non-ETOPS status. 9M-MRO was approved and had no limitations for ETOPS operations at the time of departure from Kuala Lumpur to Beijing. It was not on an ETOPS flight plan. MAS and its fleet of B777 were approved for Reduced Vertical Separation Minimum (RVSM) operation.

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[5] An AD is a notification to owners and operators of certified aircraft that a known safety deficiency with a particular model of aircraft, engine, avionics or other system exists and must be corrected. It is mandatory in nature.

[6] AWLs are items that the Certificate process has defined as critical from a fatigue or damage tolerance assessment.

[7] ETOPS is an aviation rule that allows twin-engine airliners to fly long distance routes that were previously off-limits to twin-engine aircraft.

2) Major Repair

There was an entry in the Aircraft Log Book on 09 August 2012 that the aircraft right wing tip was damaged during taxiing at Pudong, Shanghai Airport. The aircraft collided with a China Eastern Airlines A340-600, registered B-6050. The right wing tip of 9M-MRO ran into the left horizontal stabilizer of B-6050. Part of the aircraft wing tip was ruptured and stuck at the left elevator of the B-6050. *Figures 1.6A* and *1.6B* (below) show the wing tip damages.

Figure 1.6A - Right Wing Tip Damage

Figure 1.6B - Damaged Wing Tip

Boeing produced an Aircraft Survey Report reference WB175/W8134/LN404 on 15 August 2012 and the repair was carried out by Boeing Aircraft-On-Ground (AOG) Team at Pudong, Boeing Shanghai facility from 22 September to 03 October 2012. The Boeing repair scheme was approved under DCA Malaysia's Statement of Compliance (SOC) Reference Number SC/2012/081 issued on 03 September 2012. At the time of the incident, the recorded airframe hours were at 46,975:43 and landing cycles at 6,585.

There was a requirement for damage tolerance[8] information to be incorporated in the aircraft maintenance programme within 24 months from 02 October 2012 as stated in the FAA Form - Organization Designation Authorization (ODA). This damage tolerance information was not yet included in the maintenance programme for the aircraft at the time of the occurrence.

3) Cabin Configuration Change

The fleet of B777 of MAS went through a cabin interior retrofit programme which converted the configuration from 12 First Class seats/33 Business Class seats/233 Economy Class seats to 35 Business Class and 247 Economy Class seats. On 9M-MRO, this re-configuration started on 17 August 2006 and was completed on 08 September 2006. The modification was approved under FAA Supplemental Type Certificate (STC) No. STO1493SE dated 24 January 2005 and DCA's SOC No. SC2004/98.

4) Mandatory Occurrence Reports

A review of the Mandatory Occurrence Reports (MORs) for the B777 fleet raised by the Engineering & Maintenance Quality Assurance Department of MAS revealed that only one was raised for 9M-MRO, and this was related to the right wing tip damage stated above. A total of 77 MORs were raised for the MAS fleet of 17 B777 aircraft. MORs raised by the Quality Assurance department are primarily related to technical issues with the fleet. The average age of the B777 fleet as of 01 March 2014 was 14.35 years. 9M-MRO was 11.75 years old.

[8] Damage tolerance means that the structure has been evaluated to ensure that should serious fatigue, corrosion or accidental damage occurs within the operational life of the aircraft, the remaining structure can withstand reasonable loads without failure or excessive structural deformation until the damage is detected.

5) Airworthiness Directives

Maintenance and Inspection records provided by MAS indicated that at the time the aircraft 9M-MRO went missing, the aircraft and engines were fully compliant with all applicable Airworthiness Directives (AD).

The most recent AD, which was accomplished on 17 January 2014, was FAA AD 2012-13-05 which made mandatory the accomplishment of Boeing Service Bulletin 777-35A0027 which requires replacement of low pressure oxygen hoses in the cockpit. The changes provided in the service bulletin are to prevent damage to the low pressure oxygen hoses that may be subjected to electrical current. An electrical current condition in the low pressure oxygen hose can cause the low pressure oxygen hose to melt or burn. This could result in smoke and/or fire in the flight compartment. An operator (not MAS) reported that a fire originated near the first officer's area which caused extensive damage to the cockpit. One scenario of the causes being considered is that an electrical fault or short circuit resulted in electrical heating of the low pressure oxygen hoses in the flight crew oxygen system. This service bulletin is to replace low pressure oxygen hoses with non-conductive low pressure oxygen hoses located in the cockpit. The replacement of the low pressure oxygen hoses will prevent electrical current from passing through the low pressure oxygen hose internal anti-collapse spring which can cause the low pressure oxygen hose to melt or burn.

An FAA AD 2014-05-03 was issued and became effective on 09 April 2014. This AD made mandatory the accomplishment of Boeing Service Bulletin 777-53A0068 which addresses a crack in the fuselage skin under the SATCOM antenna adapter. The Service Bulletin was issued on 12 June 2013. The AD was issued to detect and correct cracking and corrosion in the fuselage skin, which could lead to rapid decompression and loss of structural integrity of the aircraft. However, this AD was not applicable to 9M-MRO as the location and configuration of the antenna on the aircraft, as delivered by Boeing ex-production, were different and not affected by the issues highlighted in the Service Bulletin.

6) Technical Log

a) MR1 and MR2

The MAS Technical Log Book was divided into Maintenance Report 1 (MR1) and Maintenance Report 2 (MR2). The MR1 has provision for the flight crew to enter any aircraft defects for each flight phase. It can also be used to enter maintenance required and rectifications by the Licenced Aircraft Maintenance Engineers (LAME) or Approval Holders, or defer defects within the Minimum Equipment List (MEL) procedures to the Maintenance Report 2 (MR2) section.

A review of the Technical Log entries for 9M-MRO since the last D check in June 2010 did not reveal any significant defects or trend.

The most recent entries made in the Technical Log Book for 9M-MRO are listed in *Appendix 1.6A.*

b) Oxygen System Replenishment

A Technical Log entry of interest, made on 07 March 2014, is the replenishment of crew oxygen system. This replenishment was reviewed in detail together with information gathered from the interview of the LAME who performed the task. Replenishment (servicing) of the crew oxygen system is a routine procedure, carried out before the minimum pressure required for departure is reached, usually carried out during a Stayover check. The minimum pressure for despatch as per the MAS Minimum Equipment List (MEL) is 310 psi at 35°C for 2-man crew and with a 2-cylinder configuration (as installed on MAS B777 fleet).

It has been the practice of the airline to service the oxygen system whenever time permits, even if the pressure is above the minimum required for despatch.

During the Stayover check on 07 March 2014, the servicing on 9M-MRO was performed by the LAME with the assistance of a mechanic, as the pressure reading was 1120 psi. The servicing was normal and nothing unusual was noticed. There was no leak in the oxygen system and the decay in pressure from the nominal value of 1850 psi was not unusual. The system was topped up to 1800 psi. Before this servicing, maintenance records showed that the system was last serviced on 14 January 2014 during an A4 check.

A small amount of oxygen is normally expended during pre-departure checks of the oxygen masks by the flight crew. Oxygen pressure is also dissipated by a bleed valve in the system for a few seconds during engine start following the end of a flight.

7) Deferred Defects (Maintenance Report 2)

A review of the aircraft records from the MAS Maintenance Control Centre (MCC) showed that the following defects were outstanding on 9M-MRO and deferred to the Deferred Defect Log (*Table 1.6C,* [below]). The hole found on the right engine acoustic panel, mentioned below in item 7, was of dimension of approximately 1 inch by 1 inch and is allowed to be deferred by the B777 Maintenance Manual until permanent repair is carried out within 500 flight hours. This minor damage is considered normal wear and tear of the engine nacelles and does not pose any hazard to the engine.

No.	Deferred Date	Defect
1.	25 Sep 2013	To carry out installation test for aft water quantity gauge.
2.	31 Oct 2013	In-Flight Entertainment (IFE) Airshow does not show arrival time/time to destination logged time & problem still persists.
3.	07 Nov 2013	From Daily Engineering Operations Report (DEOR) - Right engine consumes average 1.5T more fuel per/hour compared to left engine
4.	21 Jan 2014	Toilet 3F-1L mirror light lens broken
5.	30 Jan 2014	Pre-departure F/O seat power adjustment (fwd/aft) found inoperative.
6.	05 Mar 2014	Please check alignment for left runway turn/off light.
7.	05 Mar 2014	Hole found at 6 o'clock position of the right engine acoustic panel.

Table 1.6C - Deferred Defects

8) Engine Health Monitoring

Engine Health Monitoring (EHM) was contracted out to Rolls Royce, the engine manufacturer. Engine data 'snapshot' reports were generated by the Aircraft Condition Monitoring System (ACMS) and transmitted via ACARS to MAS, who then submitted them to Rolls Royce for analysis on its behalf. The transmitted engine parameters primarily used to assess engine health are:

- Turbine Gas Temperature
- Shaft Speeds
- Shaft Vibration (Low Pressure, Intermediate Pressure and High Pressure)
- Oil Pressure
- Oil Temperature

The EHM system trend reports over the last 3 months which covered 'snapshot' data points gathered at take-off, climb and cruise received through the ACMS show no evidence of unusual engine behaviour for both engines. On the occurrence flight, 2 EHM reports were transmitted; the first was a Take-off report generated at 1641:58 UTC, 07 March 2014 [0041:58 MYT, 08 March 2014] and the second was a Climb report at 1652:21 UTC, 07 March 2014 [0052:21 MYT, 08 March 2014]. Reports are transmitted by ACARS at convenient times during the flight (not necessarily at the time of generation/data capture). Both reports did not show any unusual engine behaviour. The data transmitted on these reports are shown in *Appendix 1.6B - Engine Health Monitoring Decoded Data for Take-off and Climb Reports*. The ACMS will also generate other pre-defined engine reports including engine parameters' exceedance reports. However, no such EHM reports were received during the flight. Position reports are also transmitted, via ACARS, every 30 minutes. Refer to *Section 1.9.4* for further details.

9) Central Maintenance Computing System

The Central Maintenance Computing System (CMCS) collects and stores information from most of the aircraft systems. It can store fault histories as well as monitor and conduct tests on the various systems. The fault history contains details of warnings, cautions and maintenance messages.

At regular intervals, during flight, the CMCS transmits any recorded fault messages, via the ACARS, to the Maintenance Control Centre (MCC) of MAS. This helps in the planning and preparation for the rectification of any potential aircraft defects at the main base or line stations.

The traffic log of maintenance messages transmitted for the last 10 flights on 9M-MRO were reviewed. There were messages transmitted, indicating that the CMCS was functioning prior to the occurrence flight. However, no maintenance messages were transmitted during the occurrence flight. These messages are transmitted in real time that is, as the faults occur.

Maintenance messages are not displayed on the Engine Indicating and Crew Alerting System (EICAS) in the cockpit and they are not used to determine the airworthiness of the aircraft. They provide diagnostic information useful in troubleshooting or maintenance planning. Only maintenance messages which trigger EICAS Alert messages require maintenance action (including deferment, if allowable) prior to despatch.

1.6.5 Weight and Balance

The aircraft underwent a scheduled reweighing on 28 April 2009 at the MAS maintenance facility at KLIA. The next aircraft re-weighing was due on or before 27 April 2014. The aircraft Weight Schedule dated 12 June 2009 was reviewed with the following pertinent details (also refer to *Table 1.6D* [below]):

- Basic Empty Weight (BEW) of 138,918.7 kg
- Centre of Gravity (C of G) position of 1,248.8 Inches
- Index of 60.07 I.U.
- C of G of 26.7 % Mean Aerodynamic Chord (MAC) Dry Operating Weight (DOW) of 145,150 kg and Index 61.13

The maximum authorised take-off weight was 286,897 kg. On the occurrence flight, the aircraft departed with a calculated take-off weight of 223,469 kg. This take-off weight was broken down as follows:

	Actual (kg)	Maximum (kg)
Take-off Weight (TOW)	223,469	286,897
Zero Fuel Weight (ZFW)	174,369	195,044
Take-off Fuel	49,100	-
Landing Weight (LDW)	186,269	208,652
Trip Fuel	37,200	-
Total Traffic Load	31,086	-
Total Payload (Load in compartment)	14,296	-
Passenger & Luggage	16,790	-
Dry Operating Weight (DOW)	143,283	-

Table 1.6D - Aircraft Weight

The balance corresponding to the aircraft take-off weight and shown on the final loadsheet (after Last Minute Changes) was 33.78% of the Mean Aerodynamic Chord (MAC) which was within limits.

During take-off, the aircraft Basic Empty Weight (BEW) was 138,918.7 kg and the C of G position was 1,248.8 inches (C of G MAC was 26.7%). Total moment was 173,478,288.65 kg in. This indicates the planned weight and balance of the aircraft was within the allowable limits. The planned cargo weight (load in compartment) of 14,296 kg and distribution matched the recorded cargo weight and distribution.

Based on the available data, the aircraft weight and balance for the take-off from Kuala Lumpur was found to be normal and within the allowable limits.

1.6.6 Fuel

The aircraft used Jet A-1 fuel. Following the previous flight, as per records in the Transit Check and Fuel Log, the total remaining fuel before refuelling as per the cockpit indication was 8,200 kg (Left Tank was 3,700 kg and Right Tank was 4,500 kg). Total departure fuel after refuelling was 49,700 kg (Left Tank was 24,900 kg and Right Tank was 24,800 kg) as indicated in the cockpit.

The fuel weight on board corresponded to a planned trip-fuel of 37,200 kg. Based on MH370 ATC flight plan dated 07 March 2014, the take-off fuel recorded was 49,100 kg. This figure differed slightly from the take-off fuel figure of 49,200 kg generated by the Aircraft Condition Monitoring System (ACMS) and transmitted by Aircraft Communications Addressing and Reporting System (ACARS). The difference was due to the actual time the fuel figure was taken from the aircraft fuel quantity indication system, by Operations for the load sheet, and by the ACMS for the ACARS report, considering fluctuations in the fuel quantity indication. The investigation estimated that the aircraft would have had 41,500 kg fuel remaining after 41 minutes flying from KLIA to IGARI.

The last position report transmitted via ACARS at 1707:29 UTC, 07 March 2014 [0107:29 MYT, 08 March 2014] recorded remaining fuel of 43,800 kg at 35,004 ft altitude.

ATC flight plan forecast recorded remaining fuel of 11,900 kg at landing, including 7,700 kg of diversion fuel. The first alternate airport, Jinan Yaoqiang International Airport (China), was estimated to be 46 minutes from the diversion point with 4,800 kg fuel required and the second alternate airport, Hangzhou Xiaoshan International Airport (China) was estimated to be 1 hour 45 minutes with 10,700 kg fuel required.

The fuel carried on board for the flight met the regulatory requirements on the minimum required, taking into account the use of possible diversion airports. There was also no evidence that more than the reasonable amount required was carried.

1.6.7 Emergency Locator Transmitter

An emergency locator transmitter (ELT) is a radio beacon that when activated will transmit digital distress signals. These signals can be tracked in order to aid the detection and localisation of an aircraft in distress.

The Fixed and Portable ELT radio beacons interface worldwide with the international Cospas-Sarsat satellite system for Search and Rescue (SAR). When activated and under satellite coverage, such beacons send out a distress signal which can be detected by satellites. The satellite receivers send this information to ground stations. This signal is transmitted to Mission Control Centres (MCC) located in six regions worldwide. The MCC covering the Indian Ocean is managed by the Australian Maritime Safety Authority based in Canberra, Australia.

ELTs are mandatory safety items carried on board the aircraft. The cabin and the technical crew attend compulsory safety emergency procedure (SEP) training and have to remain current by attending refresher SEP courses. Operation and functioning of the ELT is part of the SEP training module.

The specifications for the ELT are contained in FAA Technical Standard Orders TSO-C126 and TSO-C91A.

The ELT is a radio beacon; like all other radio equipment installed on-board, its usage is approved by the Malaysian Communications and Multimedia Commission through the Aircraft Radio Licence.
Appendix 1.6C - Copy of the Radio Licence issued for 9M-MRO.

9M-MRO had four ELTs installed. They were located as follows:

- **One FIXED ELT** located above ceiling of the aft passenger cabin at STA 1880.

  The aircraft was delivered without a fixed ELT; this component was added by MAS later (between December 2004 and July 2005). This unit is mounted to aircraft structure at the aft passenger cabin at STA 1880.

  A control switch installed in the cockpit (flight deck) aft overhead panel provides the command signal. This switch is guarded in the ARMED position. If required, the flight crew can select the ELT to ON by moving the guarded switch from ARMED to ON.

  The fixed ELT is manufactured by ELTA FRANCE and is of the 406 series, part number is 01N65900. The unit is connected to an Omni-directional, triple frequency blade antenna located at the rear fuselage forward of the vertical stabilizer at station 1881. The ELT will activate upon a sudden deceleration force per the Technical Standard Order.

  This ELT has the provision to operate on the satellite frequency of 406 MHz when activated. The transmission includes the ELT identifier, aircraft nationality and registration markings. It will also transmit on 121.5 MHz and 243 MHz when activated and these signals may be detected by air, sea or ground receivers. Transmissions on VHF frequency (121.5/243 MHz) are line of sight and effective only in close proximity (about 20 km radius).

  The battery expiry date for the FIXED ELT was November 2014.

  One PORTABLE ELT located in the forward cabin right hand coat closet.

  This closet is used by the cabin crew.

  This unit is bracket-mounted to the inside of the coat closet door. A label fixed on the coat closet door identifies the ELT. The installation allows quick removal. The Portable ELT is manufactured by ELTA FRANCE and is of the 406 series. It is identical to the fixed ELT except that this unit has its own foldable antenna. The operations and function are the same. The manufacturer part number is 01N65910.

The portable ELT has a control switch on the front face. It is normally in the OFF position. When needed, the switch can be selected to the ON position to activate the ELT transmission.

The battery expiry date for the PORTABLE ELT was November 2014.

- **Two SLIDE RAFT** mounted ELTs located at Door 1 Left and Door 4 Right (packed within the slide raft assembly).

The slide raft mounted ELT will only be available when the slide rafts at doors 1 Left or 4 Right are deployed. The ELT transmission is not satellite enabled. The transmission signal is on 121.5 MHz and 243 MHz which may be monitored with air, sea and ground-based receivers. The slide raft ELT is automatically armed when the slide raft is deployed and inflated. Once armed the ELT is automatically activated by a water sensor coming in contact with water. This ELT is not activated by deceleration. The slide raft ELTs (Part No.: P3-03-0029-10) are manufactured by DME Corporation and the battery expiry dates are as follows:

- Door 1 Left - August 2016
- Door 4 Right - May 2017

No relevant ELT beacon signals from the aircraft were reported from the responsible Search and Rescue agencies or any other aircraft.

1) Review of Effectiveness of Emergency Locator Transmitters

In general, Emergency Locator Transmitters (ELT) are intended for use on land or on the surface of water, and neither portable nor fixed ELT signals are detectable when the ELT is submerged in deep water. Portable ELT is equipped with a floatation device and can be activated by immersion in water. For effective signal transmission, the antenna of the ELT must remain above water. Damage to an ELT or its associated wiring and antenna, or shielding by aircraft wreckage or terrain, may also prevent or degrade transmission. If the portable ELT is activated within a closed aircraft the shielding effect of the aircraft structure may degrade the transmission.

a) A review of ICAO accident records over the last 30 years indicates that of the 114 accidents in which the status of ELTs was known, only 39 cases recorded effective ELT activation. This implies that of the total accidents in which ELTs were carried, only about 34% of the ELTs operated effectively (*Appendix 1.6D*).

b) The Cospas-Sarsat system has been helpful for search and rescue teams in numerous aircraft accidents on a world-wide basis. Despite these successes, the detection of ELT signals after an aircraft crash remains problematic. Several reports have identified malfunctions of the beacon triggering system, disconnection of the beacon from its antenna or destruction of the beacon as a result of accidents where aircraft was destroyed or substantially damaged. Even when the beacon and its antenna are functioning properly, signals may not be adequately transmitted to the Cospas-Sarsat satellites because of physical blockage from aircraft debris obstructing the beacon antenna or when the antenna is under water.

Source: Global Aeronautical Distress and Safety System (GADSS document)

Note:

In the aftermath of the disappearance of MH370, following a multi-disciplinary meeting in May 2014, ICAO formed an Ad-hoc Working Group on Flight Tracking with the mandate to develop a Concept of Operation on the sequence of events before and after the occurrence of an accident which should include all identified phases of such a sequence including detection of an abnormal situation, alert phase, distress phase, and search and rescue activities. This Concept of Operation is GADSS.

c) ELT can be activated automatically by shock typically encountered during aircraft crashes or manually. It is possible for Flight Crew to manually activate the ELT; however existing flight operating procedures do not call for activation of the ELT until the incident has occurred.

d) The Cospas-Sarsat system does not provide a complete coverage of the earth at all times. As a consequence, beacons located outside the areas covered by these satellites at a given moment cannot be immediately detected and must continue to transmit until a satellite passes overhead.

e) The global distress beacon detection system, Cospas-Sarsat, no longer detects 121.5 MHz distress signals. Only 406 MHz digital distress beacons are now capable of detection by satellite. Analogue beacon signals may be received by other aircraft within VHF range but there may not be such aircraft within range at the time of beacon transmission and monitoring 121.5 MHz.

1.6.8 Aircraft Systems Description

Most of the electronic equipment on the aircraft are mounted on equipment racks in the various equipment centres.

The Main Equipment Centre (MEC) contains most of the electronics equipment on the aircraft. The MEC is below the passenger cabin, rear of the nose wheel well and forward of the forward cargo compartment. Access to the MEC is possible on ground or in flight. The equipment in the MEC includes electronics for these functions:

- Information Management
- Generator Control
- Transformer Rectifier
- Flight control and autopilot
- Environmental control
- Recording
- Navigation
- Communication
- Cabin Management
- Weight and balance
- Air data
- Inertial data
- Warning
- Proximity sensing
- Engine control
- Electrical Load Management.

The Forward Equipment Centre is forward of the nose wheel well and contains the two weather radar receiver/transmitters. Access to the

Forward Equipment Centre is through the access door forward of the nose landing gear or through the MEC.

The passenger compartment above the Door 3 cross-aisle at station 1530 on the left of the aircraft centre line contains the satellite communication equipment.

A rack in the passenger compartment above the rear galley at station 2100 on the right side of the aircraft contains the flight recorders.

There are also equipment racks adjacent to the forward, aft and bulk cargo doors. The forward cargo racks contain the primary flight control, actuator control, radio altitude, fuel quantity and cargo handling electronics. The aft cargo racks contain the HF communication, brake and tire and main gear steering electronics. The bulk cargo racks contain the APU battery and charger.

1) Air Conditioning and Pressurisation

The aircraft has two air conditioning systems divided into left pack and right pack. Engine bleed air provides the pneumatic source for air conditioning and pressurisation.

There are two electronic Controllers, each of which can provide both pack and zone control. Each Controller has two channels that alternate command cycle. Cockpit and cabin temperature selection is monitored, and the Air cycle machine and temperature control valves will be commanded to deliver temperature conditioned air to the various cabin zones.

Conditioned air is also used for electronic equipment cooling. This is supplied through a series of pneumatic valves with supply and exhaust fans. Exhaust air from the equipment cooling flow is routed to the forward cargo and used for forward cargo compartment heating.

Two cabin pressure Controllers regulate the aircraft pressurisation and command the pneumatic system. System operation is automatic and works in conjunction with the forward and aft outflow valves that are used for pressurisation. The outflow valves can also be manually operated from the cockpit by switches on the overhead panel.

Loss of cabin pressure will be indicated to the flight crew by a Cabin Altitude warning message on the Engine Indicating and Crew Alerting System (EICAS) display together with the associated aural warning.

2) Autopilot Flight Director System

The autopilot is engaged by operation of either of two A/P pushbutton switches on the Mode Control Panel (MCP) located on the glareshield panel (*Figure 1.6C* [below]). Once engaged the autopilot can control the aircraft in various modes selected on the MCP. Normal autopilot disengagement is through either control wheel autopilot disengage switch. The autopilot can disengage if the flight crew override an

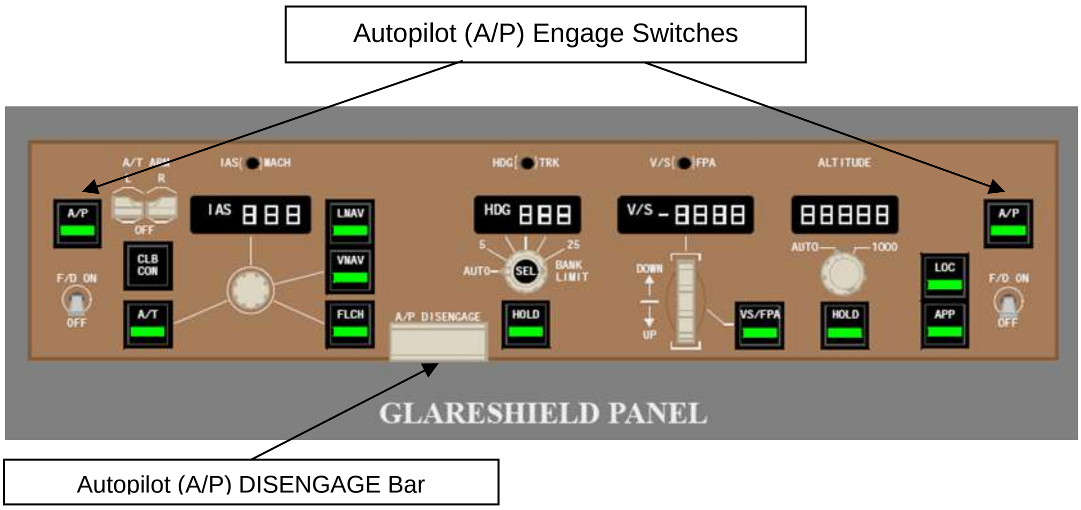

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Figure 1.6C - Autopilot Mode Control Panel

autopilot command through the use of the control column, control wheel or rudder pedals (when the yaw axis is engaged for approach).

The autopilot can also be disengaged by pulling down on the A/P Disengage Bar on the MCP. The autopilot will also disengage automatically for failures of systems on which it relies upon for specific operations. The Autopilot Flight Director System (AFDS) consists of three Autopilot Flight Director Computers (AFDCs), one MCP, and six backdrive actuators (one each for the Captain's and First Officer's control column, control wheel, and rudder pedals). The left and right 28V DC buses power the left and right AFDCs, respectively and the MCP while the 28V DC battery bus powers the centre AFDC.

Emergency power from the Ram Air Turbine (RAT) generator does not power these busses and as a result the autopilot will not function with RAT electrical power.

a) Take-off Mode

The Take-off (TO/GA) mode controls roll and pitch during take-off. Also, the Thrust Management Computing Function (TMCF) controls thrust during take-off. Turning a flight director on while the aircraft is on the ground, or activating either TO/GA switch while on the ground, will engage Take-off mode.

b) Roll Modes

The following AFDS roll modes are available during climb, cruise and descent (*Figure 1.6D* [below]*):*

i) Lateral Navigation

Pushing the Lateral Navigation (LNAV) switch arms or disarms the LNAV mode. The commands come from the active Flight Management Computing Function (FMCF) when there is a valid navigation data base and an active flight plan.

ii) Heading Hold/Track Hold

Pushing the Heading Hold (HDG HOLD)/Track hold (TRK HOLD) switch selects Heading or Track hold. In this mode, the aircraft holds either heading (HDG) or track (TRK). If the HDG/TRK display on the MCP shows TRK, the aircraft holds track. If the HDG/TRK display on the MCP shows HDG, the aircraft holds heading.

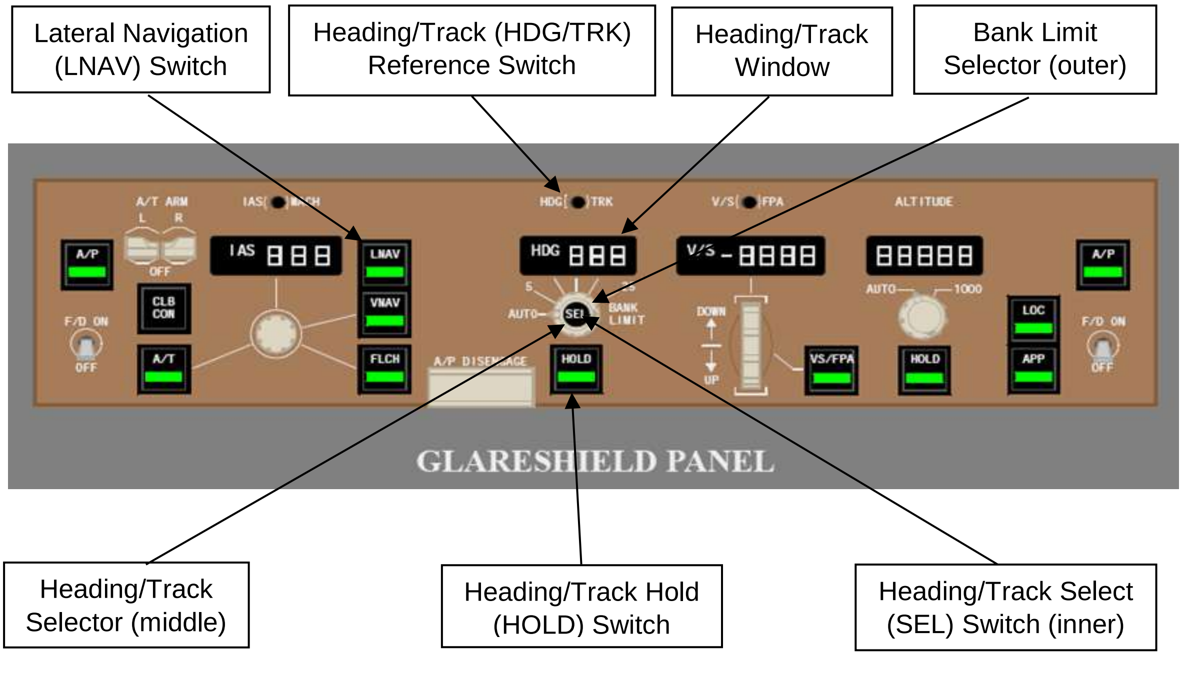

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Figure 1.6D - Lateral Mode Switches and Indicators

iii) Heading Select/Track Select

Pushing the Heading Select (HDG SEL)/Track Select (TRK SEL) switch (inner) selects Heading Select or Track Select modes. In this mode, the aircraft turns to the heading or track that shows in the heading/track window. Pushing the Heading/Track (HDG/TRK) Reference switch alternately changes the heading/track reference between heading and track. Rotating the Heading/Track selector (middle) sets the heading or track in the heading/track window. If the HDG/TRK display shows HDG, the aircraft goes to and holds the heading that shows in the heading/track window. If the HDG/TRK display shows TRK, the aircraft goes to and holds the track that shows in the heading/track window. Rotating the Bank Limit selector (outer) sets the bank limit when in the Heading Select or Track Select modes. In the AUTO position, the limit varies between 15 - 25°, depending on True Airspeed. When the other detented positions are selected, the value is the maximum, regardless of airspeed.

iv) Roll Attitude Hold

The Roll Attitude Hold mode is used to hold the roll attitude that exists at the time the flight director is first turned on, or the autopilot is first engaged. The Roll Attitude Hold mode is activated, and ATT annunciated, if the bank angle is greater than 5 degrees when either:

- A flight director is turned on with the autopilot not engaged; or
- The autopilot is initially engaged with no flight director on.

c) Pitch Modes

The following AFDS pitch modes are available during climb, cruise and descent (*Figure 1.6E* [below]):

i) Vertical Navigation

Pushing the vertical navigation (VNAV) switch arms or disarms the VNAV mode. In this mode, the AFDS uses vertical steering commands provided by the Flight Management Computer Function (FMCF). The FMCF vertical steering commands come from the active FMCF based on the navigation data and the active flight plan.

ii) Vertical Speed/Flight Path Angle

Pushing the Vertical Speed/Flight Path Angle (V/S-FPA) switch selects the V/S or FPA mode. Rotating the V/S-FPA selector Up or Down sets the vertical speed or flight path angle in the vertical speed/flight path angle window. Pushing the V/S-FPA Reference switch alternately changes vertical speed/flight path angle window references between vertical speed and flight path angle. The vertical speed or flight path angle command is an elevator command. The pilot uses this mode to change flight levels. The pilot must set the engine thrust necessary to hold the vertical speed or flight path angle command. When the V/S/FPA display shows V/S, the aircraft goes to and holds the vertical speed that shows on the vertical speed/flight path angle window.

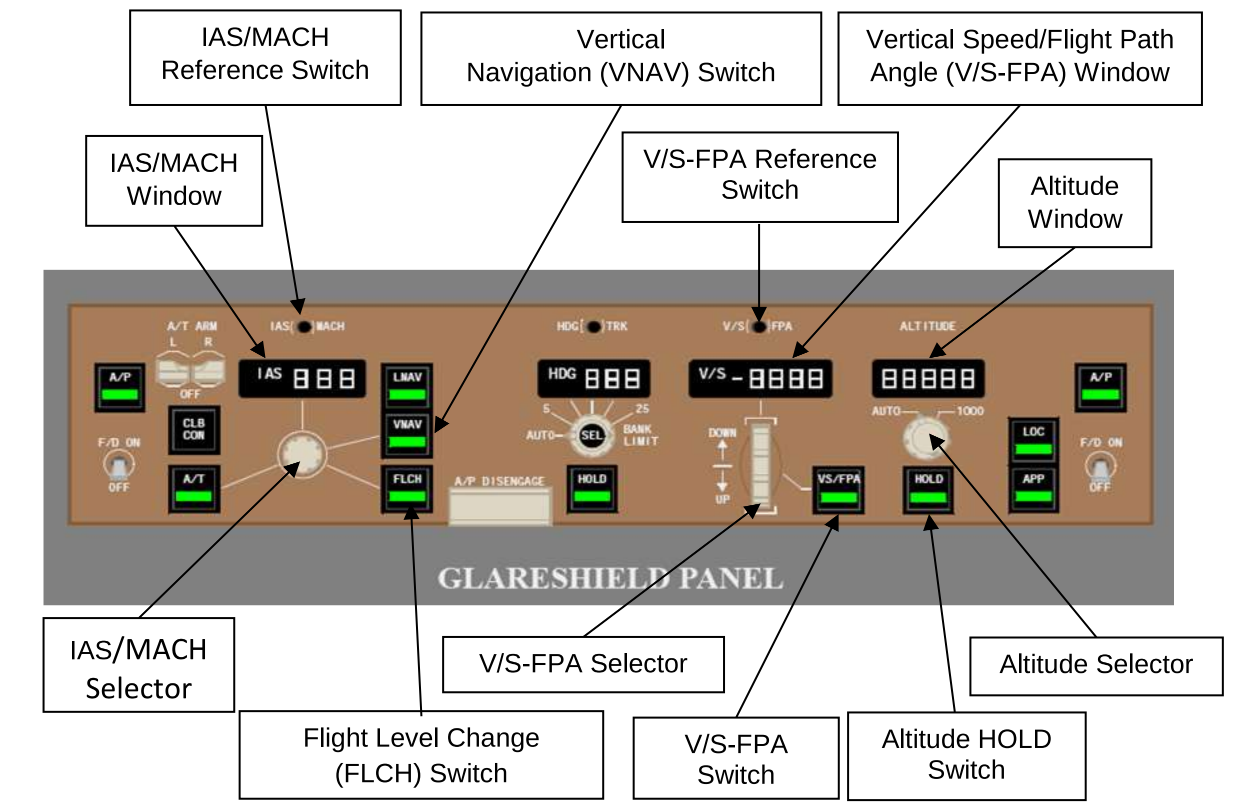

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Figure 1.6E - Vertical Mode Switches and Indicators

iii) Flight Level Change

Pushing the Flight Level Change (FLCH) switch selects the FLCH mode. In this mode, the AFDS will control to the speed target in the IAS/MACH window, providing climb and descent guidance and control. FLCH mode may be used with autothrottles, or with manual throttle control. When the IAS/MACH display shows IAS, the elevator command holds the speed that shows on the IAS/MACH window. When the IAS/MACH display shows MACH, the elevator command holds the MACH that shows on the IAS/MACH window. Rotating the IAS/MACH selector sets the speed in the IAS/MACH window. Pushing the IAS/MACH Reference switch alternately changes the IAS/MACH window between IAS and MACH. The Thrust Management Computing Function (TMCF) supplies the engine thrust commands.

iv) Altitude Hold

Pushing the Altitude Hold (ALT) switch selects the Altitude hold mode. In this mode, the aircraft holds the barometric altitude present when the pilot pushes the altitude HOLD switch. Altitude Capture and Hold can also be engaged from a climb or descent as the aircraft approaches the altitude that is selected and displayed in the altitude window.

d) Landing Modes

The following AFDS functions are available for landing:

i) Localizer

The Localizer (LOC) mode captures and holds the aircraft to a localizer flight path.

ii) Glideslope

The Glideslope (G/S) mode captures and holds the aircraft to a vertical descent flight path.

iii) Flare

The flare (FLARE) mode controls the aircraft to a smooth touchdown at a point past the glideslope antenna. This is a computed command and is not part of the glideslope mode.

iv) Runway Alignment

In crosswind conditions, the runway alignment mode supplies roll and yaw control to decrease the aircraft crab angle for touchdown. The runway alignment mode also includes roll and yaw control for an engine failure in approach during autoland.

v) Rollout

After touchdown, the rollout **(**ROLLOUT) mode controls the aircraft to the runway centre line. Aircraft deviation from the localizer centre line supplies rudder and nose wheel steering signals.

vi) Go-Around

The go-around (TO/GA) mode controls roll and pitch after an aborted approach. Also, the TMCF controls thrust during go-around.

Pushing the LOC switch arms or disarms the localizer as roll mode. Pushing the Approach (APP) switch arms or disarms the localizer as roll mode and G/S as pitch mode (*Figure 1.6F* [below]*).*

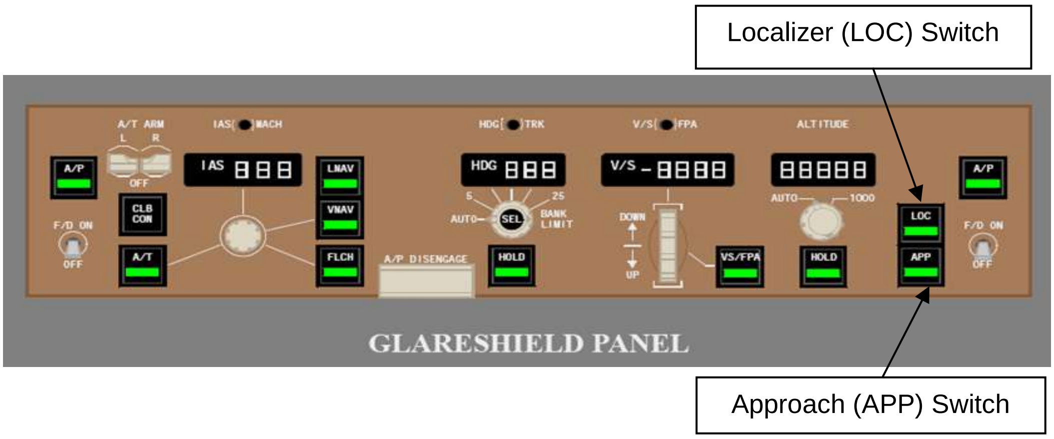

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Figure 1.6F - Approach Mode Switches

e) Autothrottle (Thrust Management Computing Function)

The autothrottle (A/T) commands the thrust levers to achieve an engine thrust setting, or a selected airspeed. The A/T is armed by raising one or both A/T Arm switches, and is engaged by a pushbutton switch on the MCP (*Figure 1.6G* [below]).

During normal flight operations, the flight crew uses the Thrust Management Computing Function (TMCF) to perform several routine or normal operations and tasks. These operations or tasks relate to autothrottle modes. The A/T modes operate in these flight phases:

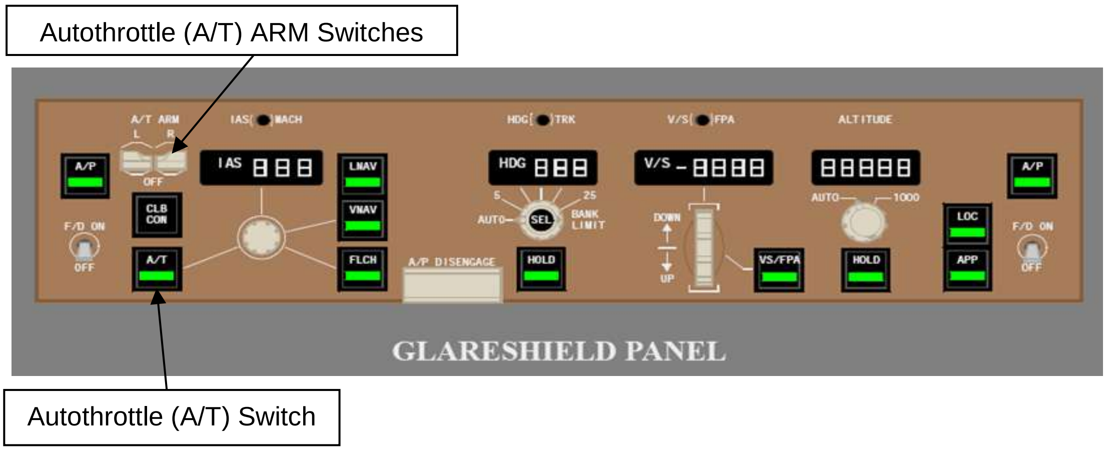

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Figure 1.6G - Autothrottle Switches

- Take-off (TO)
- Climb (CLB)
- Cruise (CRZ)
- Descent (DES)
- Approach (APP)
- Go-around (GA)

Autothrottle thrust mode annunciations relate to pitch mode annunciations on the Primary Flight Display (PFD).

f) Autothrottle Modes

i) Take-off

In take-off (TO), the autothrottle controls thrust to the TO thrust limit. The autothrottle mode annunciation on the PFD is thrust reference (THR REF). At a threshold air speed, the autothrottle mode annunciation on the PFD changes to HOLD.

ii) Climb

These are the three autothrottle mode selections in climb (CLB):

- Vertical navigation (VNAV)
- Flight level change (FLCH)

- Autothrottle (MCP) speed mode or thrust mode.

These are the autothrottle mode annunciations for these modes:

- THR REF when VNAV engages
- THR when FLCH engages
- SPD or THR REF when autothrottle mode engages.

The autothrottle speed mode only engages when VNAV, FLCH, and TO/GA are not active, and the aircraft is in the air.

iii) Cruise

In cruise, the pitch mode could be VNAV PTH, VNAV ALT or MCP ALT; the corresponding A/T mode is SPD.

iv) Descent

These are the three autothrottle modes in descent (DES):

- VNAV
- FLCH
- Autothrottle speed mode

These are the autothrottle mode annunciations in descent:

- IDLE, THR, SPD or HOLD shows for VNAV
- THR, or HOLD shows for FLCH
- SPD shows for V/S, FPA or no AFDS mode

v) Approach

SPD is normal mode in approach with glideslope active or in a manual approach (APP).

- **Go-Around**

  A go-around (GA) mode request causes the autothrottle mode to change to THR. A second GA request causes the autothrottle mode to change to THR REF. The TO/GA switch must be pushed to request GA.

- **Flare Retard**

  Flare retard occurs when a specified altitude threshold has been achieved when in SPD mode, or during an Autoland approach with a command from the autopilot flight director system (AFDS). The autothrottle mode changes to IDLE during a flare retard.

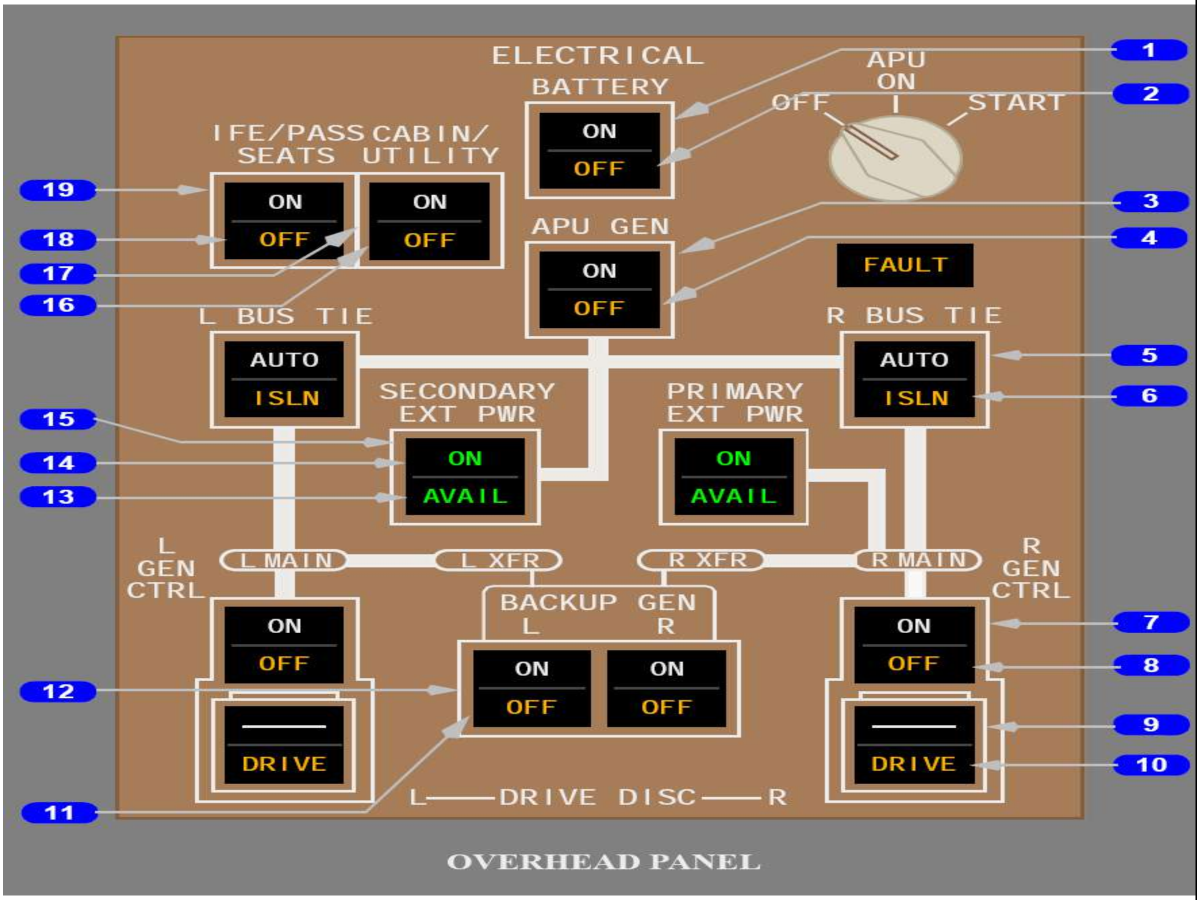
vi) Autothrottle Disconnect

The autothrottle disconnects when there is a manual autothrottle disconnect or when there is thrust reverser application. This occurs after initial touchdown during rollout. The autothrottle will disconnect automatically for certain system faults.

3) Electrical Power

The electrical system generates and distributes AC and DC power to other aircraft systems, and is comprised of: main AC power, backup power, DC power, standby power, and flight controls power. System operation is automatic. Electrical faults are automatically detected and isolated. The AC electrical system is the main source for aircraft electrical power. *Figure 1.6H* (below) shows the cockpit electrical panel where electrical switching can be made. It also shows the associated lights.

As the various aircraft systems rely on electrical power, failure of the electrical buses will affect the systems operation which will in turn trigger the corresponding fault messages. These messages are collected by the CMCS which will transmit the messages, via the ACARS, to the Maintenance Control Centre (MCC).



Electrical Power Panel Switches/Lights			
1.	Battery Switch	11.	Backup Generator OFF Lights
2.	Battery OFF Light	12.	Backup Generator (BACKUP GEN) Switches
3.	APU Generator (APU GEN) Switch	13.	External Power AVAIL Lights
4.	APU Generator OFF Light	14.	External Power ON Lights
5.	BUS TIE Switches	15.	External Power (EXT PWR) Switches
6.	BUS Isolation (ISLN) Lights	16.	CABIN/UTILITY Power OFF Light
7.	Generator Control (GEN CTRL) Switches	17.	Cabin/Utility (CABIN/UTILITY) Power Switch
8.	Generator OFF Lights	18.	IFE/PASS SEATS OFF Light
9.	Drive Disconnect Switches	19.	In Flight Entertainment System/ Passenger Seats (IFE/PASS SEATS) Power Switch
10.	Generator DRIVE Lights		

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Figure 1.6H - Electrical Power Panel Switches/Lights

a) Electrical Load Management System

The Electrical Load Management System (ELMS) provides load management and protection to ensure power is available to critical and essential equipment. If the electrical loads exceed the power available (aircraft or external), ELMS automatically shed AC loads by priority until the loads are within the capacity of the aircraft or ground power generators. The load shedding is non-essential equipment first, then utility busses. Utility busses are followed by individual equipment items powered by the main AC busses. When an additional power source becomes available or the loads decrease, ELMS restores power to shed systems (in the reverse order). The message LOAD SHED displays on the electrical synoptic when load shed conditions exist.

b) Alternating Current Electrical System Power Sources

The entire aircraft alternating current (AC) electrical load can be supplied by any two main AC power sources. The main AC electrical power sources are:

- left and right engine integrated drive generators (IDGs)
- APU generator
- primary and secondary external power

The power sources normally operate isolated from one another. During power source transfers on the ground (such as switching from the APU generator to an engine generator) operating sources are momentarily paralleled to prevent power interruption.

c) Integrated Drive Generators

Each engine has an Integrated Drive Generator (IDG). Each IDG has automatic control and system protection functions. When an engine starts, with the GENERATOR CONTROL switch selected ON, the IDG automatically powers the respective main bus. The previous power source is disconnected from that bus.

The IDG can be electrically disconnected from the busses by pushing the GENERATOR CONTROL switch to OFF. The IDG can also be electrically disconnected from its respective bus by selecting an available external power source prior to engine shutdown. The DRIVE light illuminates and the EICAS message ELEC GEN DRIVE L or R displays when low oil pressure is detected in an IDG. The IDG drive can be disconnected from the engine by pushing the respective DRIVE DISCONNECT switch. The IDG cannot be reconnected by the flight crew. High drive temperature causes the IDG to disconnect automatically.

d) Auxiliary Power Unit Generator

The Auxiliary Power Unit (APU) generator is electrically identical to the IDG generators. The APU generator can power either or both main busses and may be used in flight as a replacement to an IDG source. If no other power source is available when the APU generator becomes available, the APU generator automatically connects to both main AC busses. If the primary external source is powering both main busses, the APU powers the left main bus, and the primary external source continues to power the right main bus. If the primary external source is powering the right main bus, and the secondary external source is powering the left main bus, the APU then powers the left main bus and the primary external source continues to power the right main bus. If the secondary external source is powering both main busses, the APU then powers both main busses.

The APU generator OFF light illuminates when the APU is operating and the APU generator breaker is open because of a fault or the APU GENERATOR switch is selected OFF. When the APU GENERATOR switch is ON and a fault is detected, the APU generator cannot connect to the busses.

In flight, when both transfer busses are unpowered, the APU starts automatically, regardless of APU selector position.

e) Alternating Current Electrical Power Distribution

The AC power is distributed through the left and right main busses and the ground service bus. The right IDG normally powers the right main bus and the left IDG normally powers the left main bus. The APU normally powers both main busses when they are not powered by any other source.

Bus tie relays, controlled by BUS TIE switches, isolate or parallel the right and left main busses. When both BUS TIE switches are set to AUTO, the bus tie system operates automatically to maintain power to both main busses.

Power transfers are made without interruption when the aircraft is on the ground, except when switching between primary and secondary external power sources. The source order for powering left and right main busses in flight is the:

- respective IDG
- APU generator
- opposite IDG

f) Autoland

During autoland, the busses isolate to allow three independent sources to power the three autopilots:

- the left IDG powers the left AC transfer bus, the left main DC bus, and the captain's flight instrument bus;
- the right IDG powers the battery bus and AC standby bus through the main battery charger; and
- the back-up system powers the right AC transfer bus, the right DC bus, and the first officer's flight instrument bus.

g) Backup Alternating Current Electrical System

The electrical system is highly reconfigurable to accommodate multiple failures. The electrical system is designed to automatically provide power to selected aircraft systems. The electrical system automatically powers one or both transfer busses when:

- only one main AC generator (includes APU) is available;
- power to one or both of the main AC busses is lost;
- approach (APP) mode is selected for autoland; and
- the system is automatically tested after engine starts

The system automatically transfers power without interruption.

h) Backup Generators

Backup power is provided by one variable speed, variable frequency generator mounted on each engine. A frequency converter converts the generator frequency to a constant 400 Hz. Only one backup generator can power the converter at a time.

Each backup generator contains two permanent magnet generators (PMGs) that supply power to the flight control DC electrical system (refer to DC Electrical System). If both IDGs and the APU generator are inoperative, a backup generator powers essential aircraft equipment. To reduce electrical loading on the backup generator, the following systems are inoperative:

- TCAS
- SATCOM
- Right HF radio

i) Direct Current Electrical System

The direct current (DC) electrical system includes the main DC electrical system and the flight control DC electrical system. The main DC electrical system uses four transformer-rectifier units (TRUs) to produce DC power. The TRUs are powered by the AC transfer busses.

TRU DC electrical power is distributed to various DC busses as follows:

(1) The left TRU powers the left main DC bus, which provides a second DC power source for:

- left flight control power supply assembly (PSA)
- right main DC bus.

(2) The right TRU powers the right main DC bus, which provides a second DC power source for:

- right flight control PSA
- left main DC bus.

(3) The C1 TRU powers the captain's flight instrument bus and the battery bus. The captain's flight instrument bus provides a second DC power source for:

- centre flight control PSA
- first officer's flight instrument bus

The C2 TRU powers the first officer's flight instrument bus, which provides a second DC power source for the captain's instrument bus.

j) Batteries

The main battery is connected directly to the hot battery bus and provides standby power to other busses. The main battery charger normally powers the hot battery bus and maintains the main battery fully charged.

The APU battery is connected directly to the APU battery bus and provides dedicated power to the APU electric starter, which is used when sufficient bleed air duct pressure is unavailable for the APU air turbine starter. The APU battery charger normally powers the APU battery bus and maintains the APU battery fully charged.

k) Flight Control Direct Current Electrical System

The flight control DC electrical system is a dedicated power source for the primary flight control system. Primary power for the flight control DC electrical system comes from permanent magnet generators (PMGs) housed within each backup generator. Variable frequency PMG AC power is used by individual power supply assemblies (PSAs) to provide DC power to the three flight control DC busses. To ensure a high level of system reliability, each PSA also has multiple DC power sources. If primary PMG AC power is not available, secondary power for the left and right PSAs is provided by the related main DC bus. Secondary power for the centre PSA is provided by the captain's flight instrument bus. The hot battery bus provides additional backup power for the left and centre PSAs only. Each PSA also uses a dedicated battery to prevent power interruptions to the related flight control DC bus. The batteries have limited capacity and are incorporated to supply power for brief periods during PSA power source transfers.

l) Standby Electrical System

The standby electrical system can supply AC and DC power to selected flight instruments, communications and navigation systems, and the flight control system, if there are primary electrical power system failures. The standby electrical system consists of:

- the main battery
- the standby inverter
- the RAT generator and its associated generator control unit
- the C1 and C2 TRUs

(1) Main Battery

The main battery provides standby power to the:

- hot battery bus
- battery bus
- captain's flight instrument bus
- left and centre flight control PSAs
- standby inverter.

Note:

The main battery can power the standby system for a minimum of 10 minutes.

(2) Standby Inverter

The standby inverter converts DC power to AC power. The inverter powers the AC standby bus if the left transfer bus is not powered.

(3) Ram Air Turbine Generator

The ram air turbine (RAT) generator provides standby power to the C1 and C2 TRUs. The RAT can supply electrical and hydraulic power simultaneously. If the RAT is unable to maintain RPM, the RAT generator electrical load is shed until RPM is satisfactory. Power for standby electrical loads is provided by the main battery during deployment of the RAT and when RAT generator loads are shed. The RAT is deployed automatically if both AC transfer busses lose power in flight. The RAT can be manually deployed by using the RAM AIR TURBINE switch on the overhead panel.

(4) Cabin Systems and Utility Power

Electrical power to some cabin and utility systems are controlled from the cockpit. The IFE/PASS SEATS Power switch controls power to the IFE and passenger seats. The CABIN/UTILITY Power switch controls power to cabin and utility systems.

4) Cabin and Cargo Compartments

The aircraft, 9M-MRO was configured to 35 business class and 247 economy class seats. The business class and economy class seats were procured from BE Aerospace. An approved Lay Out of Passenger Accommodation (LOPA) determines the cabin interior configuration. Safety and emergency equipment are fitted and positioned throughout the cabin.

There is one crew rest area in the forward cabin behind the cockpit. There is a cabin crew rest area in the aft cabin lower lobe. Access is through a compartment door adjacent to Door 3R.

The cockpit door provides selective entry to the cockpit and is resistant to ballistic penetration. When closed, the door locks when electrical power is available and unlocks when electrical power is removed. A viewing lens in the door allows observation of the cabin. The door can be manually opened from the cockpit by turning the door handle.

An emergency access code is used to gain access to the cockpit in case of pilot incapacitation. Access is provided by the use of a Keypad Access System which consists of a numeric keypad outside the cockpit area and a chime module and electric strike that is not accessible from outside the cockpit. The chime module provides an audible alert to the pilots that the correct code has been entered into the keypad. There is also an indicator light in the cockpit and a Light Emitting Diode (LED) on the keypad that indicates that the correct code has been entered.

The pilots have a 3-position switch by which they can open the door lock, close the door lock, or permanently lock the door for a specified amount of time to prevent access by anyone regardless if the correct code is entered into the keypad.

The door has blowout panels that will open in the event of a rapid decompression of the passenger compartment. A pressure sensor controls an electric strike and allows the door to open inward in the event of a rapid decompression in the cockpit. These features serve to equalise the pressure between the passenger compartment and the cockpit in case of decompression either side of the door.

The aircraft is also fitted with a Flight Deck Entry Video Surveillance System (FDEVSS) which provides the pilots surveillance capability of the cockpit doorway and the forward galley areas. This allows the pilots to see the person who wants to access the cockpit before they allow entry.

There are four Type A passenger and service doors on each side of the aircraft. Each door has a window. The passenger compartment has windows along both sides of the passenger compartment. Each exit is fitted with a slide raft system for emergency use.

The overhead passenger cabin is fitted with Passenger Service Units (PSU) above each seat row. They are hinged and secured by a magnetic latch that is electrically controlled. In the event of cabin depressurisation, the PSU magnetic latch will be electrically released and allow the oxygen masks to drop for passenger use.

The aircraft cabin lighting system comprises of ceiling lights, sidewall lights, entry lights and emergency lights. The cabin management system (CMS) controls the passenger cabin lighting.

The lower section of the fuselage houses forward, aft and bulk cargo compartments. A cargo handling system is fitted for the forward and aft cargo to command power drive units (PDU) to move cargo containers laterally and longitudinally.

Cargo compartment sidewalls, ceilings and walkways are constructed of fire resistant materials. There is a smoke detection warning system and fire extinguishing system installed to contain any smoke or fire eventualities.

5) Flight Controls

The flight control system is an electronic fly by wire system. It is divided into two separate systems to control the aircraft in flight.

Primary Flight control system (PFCS) is a modern three axis, fly by wire system. It controls the roll, yaw and pitch commands using the ailerons, flaperons, spoilers, elevators, rudder and horizontal stabilizer. The high lift control system (HLCS) comprises of inboard and outboard trailing edge flaps, leading edge flaps and Kruger flaps. It supplies increased lift at lower speeds for take-off and landing.

The PFCS and HLCS use 3 dedicated ARINC 629[9] Flight Control digital busses to transmit data signals to command the flight controls. Mechanical control is available to two spoilers and horizontal stabilizers.

The PFCS has three operational modes of command - Normal mode, Secondary mode and Direct mode. The PFCS command signals are computed by three redundant Primary Flight Computers (PFCs) in Normal and Secondary modes and directed through four Actuator Control Electronic (ACE) units. In Direct mode, the control surface command signals are computed by the ACEs without reliance on the PFCs.

The PFC also receives airspeed, altitude and inertial reference data from Airplane Information Management System (AIMS), Air Data Inertial Reference Unit (ADIRU) and Secondary Attitude and Air Data Reference unit (SAARU). The PFCs calculate the flight control commands based on control laws, augmentation and envelop protections. The digital command signals from the PFCs go to the ACEs that will change the digital signal to analogue format and send to the power control units (PCU) that will command the control surface movement.

The HLCS operates in three modes, primary, secondary and alternate. Command signals are transmitted from the flap lever to two Flap Slat Electronic Units (FSEU).

The FSEU process the flap command and control the sequence of flaps and slats operation. It also commands auto slat, load relief and asymmetry protection.

Two spoilers and the horizontal stabilizer receive mechanical control signals from pilots input.

[9] *Aeronautical Radio, Incorporated (ARINC) 629 is an aeronautical standard which specifies multi-transmitter data bus protocol where up to 128 units can share the same bus.*

6) Fuel System

The fuel system has three fuel tanks, two integral wing tanks and one centre tank. The tanks are part of the wing structure and have many fuel system components located inside the tanks and on the rear spar. The fuel tanks are vented through channels in the wing to allow near ambient pressure during all phases of flight.

An integrated refuel panel (IRP) on the lower left wing and two refuel receptacles on each wing allows rapid pressure refueling of the aircraft. The refueling operation is automatic with fuel load selection on the IRP. Fuel quantity indicating system (FQIS) processor unit controls all fueling operations and measuring of fuel quantity.

Several enhanced features were incorporated in the design to include the following:

- Ultrasonic Fuel Quantity Indicating system
- Automatic centre tank scavenge system
- Ultrasonic water detection system
- Densitometers
- Jettison system

Fuel quantity is displayed on the fuel synoptic page and the upper EICAS fuel block.

a) Engine Fuel Feed System

There are two boost pumps for each main tank and two override/ jettison pumps in the center tank to supply fuel to the engines. The fuel flows through the crossfeed manifold to the engines. Redundant crossfeed valves isolate the left and right sides of the manifold.

At the start of a flight, when all the tanks are full, the normal procedure is to turn on all the fuel pumps. The override/jettison pumps supply center tank fuel to both engines. This occurs because the override/jettison pumps have a higher output pressure than the main tank boost pumps. When the override/jettison pump output pressure decreases because of low fuel quantity in the center tank, the boost pumps automatically supply fuel to both engines from the main tanks.

b) Auxiliary Power Unit Fuel Feed System

The Auxiliary Power Unit (APU) can receive fuel from any tank. A DC pump supplies fuel from the left main tank if no AC power is available. APU fuel is supplied from the left fuel manifold. APU fuel can be provided by any AC fuel pump supplying fuel to the left fuel manifold or by the left main tank DC fuel pump. On the ground, with the APU switch ON and no AC power available, the DC pump runs automatically. With AC power available, the left forward AC fuel pump operates automatically, regardless of fuel pump switch position, and the DC fuel pump turns off. In flight, the DC fuel pump operates automatically for quick left engine relight with the loss of both engines and all AC power. *Figure 1.6I* (below) shows the Engine and APU Fuel Feed System.

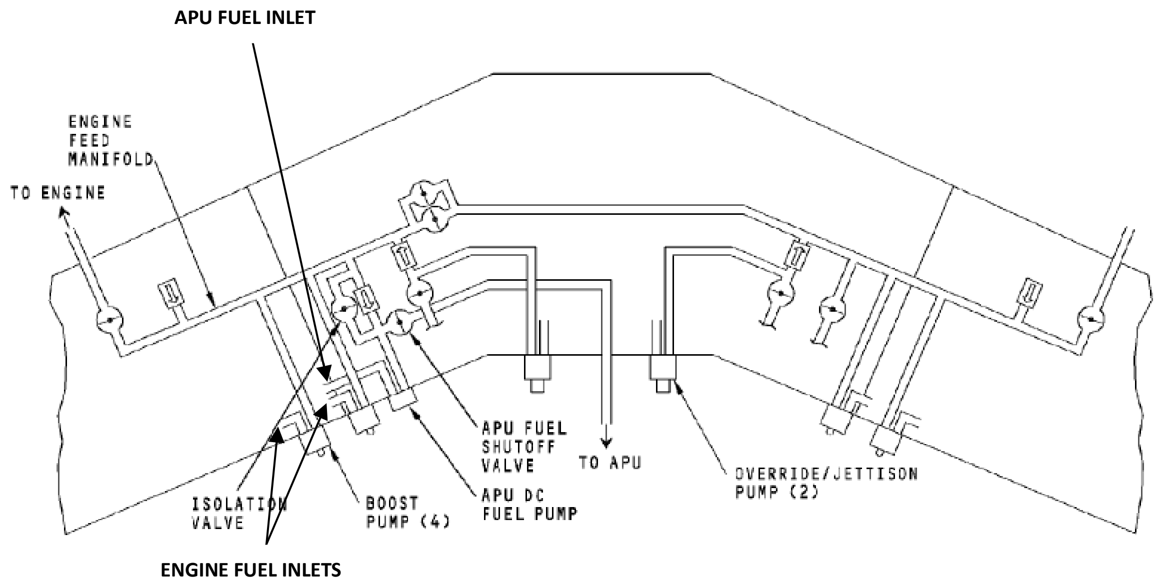

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Figure 1.6I - Engine and APU Fuel Feed

c) Fuel Inlets

The fuel intake inlet for the APU (in the left main tank) is located lower than that for the engine. As the fuel level drops below the engine fuel intake level the engine will be starved of fuel, however fuel will still be available for the APU as its fuel intake is lower. This difference in level between the engine and APU fuel intakes, accounts for approximately 30 pounds of fuel in a standard flight attitude (1° pitch). The APU is estimated to consume (when electrically loaded) approximately 2 pounds of fuel in 55 seconds which will amount to a maximum APU run time of 13 minutes and 45 seconds. The pitch attitude and in-flight accelerations can affect the actual amount available for the APU.

7) Hydraulics

There are three independent hydraulic systems using electrical, pneumatics or engine driven power source. They are identified as Left, Centre and Right. Each hydraulic system can independently operate the flight controls for safe flight and landing.

Each hydraulic system uses a Hydraulic Interface Module Electronics Card (HYDIM) for automatic control and indications. The three systems operate independently at 3000 psi nominal pressure.

The left system is powered by an engine driven pump (EDP) and an electric motor pump (ACMP). The right system is also powered by an EDP and ACMP. The centre system has two ACMP and two air driven pumps (ADP) and a ram air turbine (RAT) pump.

Hydraulic pumps control and indication are on the P5 overhead panel. During normal operation the flight crew will select the switches to the auto position before flight. The pressure and quantity indication is provided on the hydraulic synoptic page and the status page.

The primary pumps are the EDPs in the left and right system and the ACMPs for the centre system. These pumps operate continuously. The demand pumps are the ACMPs for the left and right systems and the ADPs for the centre system. These pumps normally operate only during heavy system demands. The operation logic is controlled and monitored by the HYDIM cards.

The RAT deploys automatically during flight when both engines are shutdown or for loss of all three hydraulic power. The RAT hydraulic pump supplies hydraulic power to some of the center hydraulic system flight controls. When the aircraft is operating on RAT power only, the flap drive hydraulic motor is isolated from the center hydraulic system and as a result the flaps will not respond to the cockpit flap handle inputs.

8) Instrumentation

The flight instruments and displays supply information to the flight crew on six flat panel liquid crystal display units:

- Captain and First Officer Primary Flight Display (PFD)
- Captain and First Officer Navigation Display (ND)
- Engine Indication and Crew Alerting System (EICAS)
- the Multifunction Display (MFD)

Standby Flight Instruments provide information on separate indicators. Clocks display Airplane Information Management System (AIMS) generated UTC time and date, or manually set time and date.

a) Primary Flight Display

The Primary Flight Display (PFD) presents a dynamic color display of all the parameters necessary for flight path control. The PFDs provide the following information:

- flight mode annunciation
- airspeed
- altitude
- vertical speed
- attitude
- steering information
- radio altitude
- instrument landing system display
- approach minimums
- heading/track indications, engine fail, Ground Proximity Warning System (GPWS), and Predictive Windshear (PWS) alerts.

Failure flags are displayed for aircraft system failures. Displayed information is removed or replaced by dashes if no valid information is available to the display system (because of out-of-range or malfunctioning navigation aids). Displays are removed when a source fails or when no system source information is available.

b) Navigation Display

The navigation displays (ND) provide a mode-selectable color flight progress display. The modes are:

- MAP
- VOR
- APP (approach)
- PLN (plan)

The MAP, VOR, and APP modes can be switched between an expanded mode with a partial compass rose and a centered mode with a full compass rose.

c) Engine Indication and Crew Alerting System

The Engine Indication and Crew Alerting System (EICAS) consolidates engine and aircraft system indications and is the primary means of displaying system indications and alerts to the flight crew. The most important indications are displayed on EICAS which is normally displayed on the upper centre display.

i) System Alert Level Definitions

(1) Time Critical Warnings

Time critical warnings alert the crew of a non-normal operational condition requiring immediate crew awareness and corrective action to maintain safe flight. Master warning lights, voice alerts, and ADI indications or stick shakers announce time critical conditions.

(2) Warnings

Warnings alert the crew to a non-normal operational or system condition requiring immediate crew awareness and corrective action.

(3) Cautions

Cautions alert the crew to a non-normal operational or system condition requiring immediate crew awareness. Corrective action may be required.

(4) Advisories

Advisories alert the crew to a non-normal operational or system condition requiring routine crew awareness. Corrective action may be required.

(5) Engine Indication and Crew Alerting System Messages

Systems conditions and configuration information are provided to the crew by four types of EICAS messages:

- EICAS alert messages are the primary method to alert the crew to non-normal conditions.
- EICAS communication messages direct the crew to normal communication conditions and messages.
- EICAS memo messages are crew reminders of certain flight crew selected normal conditions.
- EICAS status messages indicate equipment faults which may affect aircraft capability.

An EICAS alert, communications, or memo message is no longer displayed when the respective condition no longer exists.

d) Multifunction Display

The electronic checklist (ECL) system shows normal and non-normal checklists on a multifunction display (MFD). The electronic checklist system is not required for, and a paper checklist or other approved backup checklist must be available in the cockpit.

The checklist display switch on the display select panel opens the electronic checklist. The flight crew operates the checklist with the cursor control devices (CCDs).

The MFD has also communications functions which are used to control data link features. Data link messages not processed by the Flight Management Computer (FMC) are received, accepted, rejected, reviewed, composed, sent, and printed using communications functions on the MFD. ACARS and data link radio management functions are provided through communications management menus. The COMM display switch, located on the display select panel, displays the communications main menu on the selected MFD.

Communications functions are selected using the cursor control device. Message text entry is accomplished by entering data into the Control Display Unit (CDU) scratchpad and transferring it to the appropriate area. Messages can be printed on the cockpit printer. Incoming message traffic is annunciated by EICAS communications messages.

e) Standby Flight Instruments

The standby flight instruments include:

- standby attitude indicator
- standby airspeed indicator
- standby altimeter
- standby magnetic compass

An external Power Supply Assembly supplies power to the standby attitude and airspeed indicators and the standby altimeter. The standby magnetic compass does not require any electrical power except for its lighting.

(1) Standby Attitude Indicator

The Standby Attitude Indicator displays Secondary Attitude Air Data Reference Unit (SAARU) attitude. A bank indicator and pitch scale are provided.

(2) Standby Airspeed Indicator

The Standby Airspeed Indicator displays airspeed calculated from two standby air data modules (one pitot and one static). It provides current airspeed in knots as a digital readout box with an airspeed pointer.

(3) Standby Altimeter

The standby altimeter displays altitude from the standby (static) air data module. Current altitude is displayed digitally. A pointer indicates altitude in hundreds of feet. The pointer makes one complete revolution at appropriate intervals.

(4) Standby Magnetic Compass

A standard liquid–damped magnetic standby compass is provided. A card located near the compass provides heading correction factors.

f) Clock

A clock is located on each forward panel. Each clock displays Airplane Information Management System (AIMS) generated UTC time and date, or manually set time and date. The AIMS UTC time comes from the global positioning system (GPS). In addition to time, the clocks also provide alternating day-month and year, elapsed time, and chronograph functions.

9) Airplane Information Management System

The Airplane Information Management System (AIMS) collects and calculates large quantities of data. The AIMS manages this data for several integrated avionics systems. These systems are the:

- Primary display system (PDS)
- Central maintenance computing system (CMCS)
- Airplane condition monitoring system (ACMS)
- Flight data recorder system (FDRS)
- Data communication management system (DCMS) - including ACARS datalink
- Flight management computing system (FMCS)
- Thrust management computing system (TMCS)

The AIMS has software functions that do the calculation for each of these avionics systems. The AIMS supplies one other software function that many aircraft systems use. It is the data conversion gateway function (DCGF).

The AIMS has two cabinets, for redundancy, which do the calculations for other avionic systems. The Left cabinet is located in the forward rack of the Main Equipment Centre (MEC) while the Right cabinet is located in rear rack of the MEC. To do these calculations, each AIMS cabinet has the following:

- A cabinet chassis
- Four Input/output modules (IOM)

- Four Core processor modules (CPM)

The IOMs and CPMs are considered Line Replaceable Modules (LRM). The IOM transfers data between the software functions in the AIMS CPMs and external signal sources. The CPMs supply the software and hardware to do the calculations for several avionic systems. The software is called functions. To keep a necessary separation between the functions, each function is partitioned. The partitions permit multiple functions to use the same hardware and be in the same CPM.

The Left AIMS cabinet gets electrical power from the 28V DC Capt Flight Instrument bus and the 28V DC F/O Flight Instrument bus. The Right AIMS cabinet gets electrical power from the 28V DC Left bus and the 28V DC Right bus. Each cabinet receives the power from four 28V DC circuit breakers in the overhead circuit breaker panel. The four 28V DC bus inputs are known as power 1 through power 4. Power 1 and power 2 enter the cabinet through a connector on the left side of the cabinet and therefore they are considered as left power. Power 3 and power 4 enter the cabinet through a connector on the right side of the cabinet and are considered as right power.

Each LRM receives power from four sources, two for main power and two for monitor power. The main circuitry uses the main power. Special circuits that monitor the condition of the power supply in the LRM use the monitor power. The two main and two monitor sources of power for each LRM come from different power sources.

Each AIMS cabinet also receives power through one hot battery bus circuit breaker in the standby power management panel. The connection to the hot battery bus keeps the LRMs internal memories active. The hot battery bus also makes the AIMS cabinet less likely to have faults due to power transients.

10) Navigation Systems

The Navigation systems of interest include Global Positioning System (GPS), Air Data Inertial Reference System (ADIRS) and the Flight Management System (FMS).

a) Global Positioning System

The Left and right GPS receivers are independent and use navigation satellites to supply very accurate position data to the

FMC. One is powered by the 115V AC Standby bus and the other by the 115V AC Transfer bus. They pass data to aircraft systems including the ADIRS via the AIMS. GPS tuning is automatic. If the Air Data Inertial Reference Unit (ADIRU) becomes inoperative during flight, the EICAS displays the message NAV ADIRU INERTIAL and the FMC uses only GPS data to navigate.

b) Inertial System

The ADIRS calculates aircraft altitude, airspeed, attitude, heading, and position data for the displays, flight management system, flight controls, engine controls, and other systems. The major components of ADIRS are the ADIRU, Secondary Attitude and Air Data Reference Unit (SAARU), and air data modules. The ADIRU supplies primary flight data, inertial reference, and air data. The ADIRU is fault-tolerant and fully redundant. The SAARU is a secondary source of critical flight data for displays, flight control systems, and other systems. If the ADIRU fails, the SAARU automatically supplies attitude, heading, and air data. SAARU heading must be manually set to the standby compass magnetic heading periodically. The ADIRU and SAARU receive air data from the same three sources. The ADIRU and SAARU validate the air data before it may be used for navigation. The three air data sources are the left, centre, and right pitot and static systems.

c) Flight Management System

The FMS aids the flight crew with navigation, in-flight performance optimisation, automatic fuel monitoring, and cockpit displays. Automatic flight functions manage the aircraft lateral flight path (LNAV) and vertical flight path (VNAV). The displays include a map for aircraft orientation and command markers on the airspeed, altitude, and thrust indicators to help in flying efficient profiles. The flight crew enters the applicable route and flight data into the CDUs. The FMS then uses the navigation database, aircraft position, and supporting system data to calculate commands for manual and automatic flight path control. The FMS tunes the navigation radios and sets courses. The FMS navigation database supplies the necessary data to fly routes, SIDs, STARs, holding patterns, and procedure turns. Cruise altitudes and crossing altitude restrictions are used to calculate VNAV commands. Lateral offsets from the programmed route can be calculated and commanded.

The basis of the flight management system is the flight management computer function. Under normal conditions, one Flight Management Computer (FMC) accomplishes the flight management tasks while the other FMC monitors. The second FMC is ready to replace the first FMC if system faults occur. The FMC uses flight crew-entered flight plan data, aircraft systems data, and data from the FMC navigation database to calculate aircraft present position and pitch, roll, and thrust commands necessary to fly an optimum flight profile. The FMC sends these commands to the autothrottle, autopilot, and flight director. Map and route data are sent to the NDs. The EFIS control panels select the necessary data for the ND. The mode control panel selects the autothrottle, autopilot, and flight director operating modes.

Crew Procedure on the operations and programming of the Flight Management System safeguards and protects against incorrect execution of erroneous Information for the Navigation and Performance Data Input. Different levels of verification and cross checking between the Captain and Co-Pilot ensure that any error would be captured and corrected during the crew preparation.

In addition, system logics will also prevent the crew against selection of the wrong co-ordinates from the stored Navigation Database if a particular waypoint code happens to be used by many different places worldwide.

11) Oxygen Systems

a) Flight Crew Oxygen System

The flight crew oxygen system provides oxygen to the flight crew for emergencies and other procedures which make its use necessary. The oxygen is supplied by two cylinders located in the left side of the main equipment centre. Each cylinder is made of composite material and holds 115 cubic feet (3,256 litres) of oxygen at 1,850 psi. The oxygen is supplied, through regulators, to four oxygen masks in the cockpit, one each for the Captain, the First Officer, the First Observer and the Second Observer. The mask has a dilution control which is normally set at ‘Normal’ position. In this position the oxygen is diluted with ambient air according to the pressure altitude in the cockpit. It can also be selected to '100%', in which case 100% oxygen will be supplied. *Table 1.6E* (below) shows the expected duration of oxygen supply from the two cylinders with the dilution control in 'Normal' position.

AIRCRAFT ALTITUDE: 36,000 ft			
Cabin Altitude: 8,000 ft.		**Cabin Altitude: 36,000 ft.**	
No. of Crew Members	**Expected Duration (hour)**	**No. of Crew Members**	**Expected Duration (hour)**
1	42	1	27
2	21	2	13
3	14	3	9
4	10.5	4	6.5

Table 1.6E - Expected Duration of Crew Oxygen

Aircraft altitude is assumed to be 36,000 ft. A cabin altitude of 8,000 ft. would indicate a normally pressurised cabin and a cabin altitude of 36,000 ft. would indicate an unpressurised cabin. At this cabin altitude of 36,000 ft, 100% oxygen will be supplied even with the dilution control in the 'Normal' position.

b) Passenger Oxygen System

The passenger oxygen system is supplied by separate and individual chemical oxygen generators. The oxygen system provides oxygen to:

- passenger seats
- attendant stations
- lower crew rest compartment
- lavatory service units

The passenger oxygen masks and chemical oxygen generators are located in passenger service units (PSUs). A door with an electrically operated latch keeps the masks in a box until the oxygen deployment circuit operates. The deployment circuit operates, and the masks automatically drop from the PSUs if cabin altitude exceeds approximately 13,500 feet. The passenger masks can be manually deployed from the cockpit by pushing the overhead panel PASSENGER OXYGEN switch to the ON position. Oxygen flows from a PSU generator when any mask hanging from that PSU is pulled. Oxygen is available for approximately 22 minutes. The electrical power to the latch is supplied through a circuit breaker located in the Main Equipment Centre. It is not possible to deactivate automatic deployment of the masks from the cockpit.

c) Portable Oxygen

Portable oxygen cylinder lets the flight attendants move in the aircraft when oxygen is in use. It is also a gaseous oxygen supply for medical emergencies. The bottle is fitted with disposable mask. 15 cylinders are located throughout the passenger cabin. Each cylinder is of 11 cubic ft (310 litres) capacity. The flow of oxygen can be controlled by an ‘Off-On’ knob which can be rotated to control the flow from 0 to 20 litres per minute. Therefore, the minimum time for the portable oxygen supply from full is 15.5 minutes.

12) Central Maintenance Computing System

The Central Maintenance Computing System (CMCS) collects and stores information from most of the aircraft systems. It can store fault histories as well as monitor and conduct tests on the various systems. The fault history contains details of warnings, cautions and maintenance messages.

At regular intervals, during flight, the CMCS transmits any recorded fault messages, via the Aircraft Communications Addressing and Reporting System (ACARS), to the Maintenance Control Centre (MCC) of Malaysia Airlines. This helps in the planning and preparation for the rectification of any potential aircraft defects at the main base or line stations. Refer also to *Section 1.6.4 para. 9)*.

13) Engines

The aircraft is fitted with two engines (Model: RB211 TRENT 892B-17) manufactured by Rolls-Royce. The RB211 TRENT 892B-17 engine is a high bypass turbofan (bypass ratio of 6.4:1 at a typical cruise thrust) axial flow, three-rotor with a single low pressure fan driven by a five-stage, low-pressure turbine.

The engine has an eight-stage intermediate pressure compressor driven by a single-stage turbine and a six-stage high pressure compressor driven by a single-stage turbine.

The engine take-off thrust is 92,800 lb and weighing approximately 15,700 lb (7,136 kg). The engines are certified in accordance with the US FAA Type Certificate E00050EN.

The FAA Type Certificate Data Sheet certifies that the engines meet the smoke and gaseous emission requirements of the US FAR 34. The engine is certified under FAR Part 36 Stage 3 Noise regulation.

The engine is fitted with a digital Electronic Engine Fuel Control System and it interfaces with many systems and components in the form of primary analogue or ARINC 629 buses.

The following analogue engine fuel and control system interfaces and correlates with the other systems for supply and feedback:

- Engine ignition - ignition unit power
- Engine air - actuator and valves
- Engine controls - resolver excitation and position
- Engine indicating - engine parameter data
- Engine exhaust - thrust reverser operations
- Engine oil - oil cooling and indications
- Engine starting - auto-start and manual start
- Electrical power - aircraft power from the Electrical Load Management System (ELMS)

The following ARINC 629 engine fuel and control system interfaces and correlates with other systems for supply, control and indication data:

- AIMS - indication, air data and flight management control
- Cockpit controls - switch position and indication
- Flap Slat Electronic Unit (FSEU) - Flap indication
- Proximity Switch Electronic Unit (PSEU) - Landing gear lever position
- Air Supply Cabin Pressure Controller (ASCPC) - Pneumatic system demand

The RB211 TRENT 892B-17 engine Electronic Engine Control (EEC) serves as the primary component of the engine fuel control system and uses data from the engine sensors and aircraft systems to control the engine operations. The EEC controls most of the engine components and receives feedback from them. These digital data go to the Engine Data Interface Unit (EDIU) and send the signal to the AIMS. The AIMS transmits and receives a large amount of data to and from the EEC. These include:

- Engine bleed status - EEC thrust limit calculations
- Air data - EEC thrust limit calculations
- Engine data – system requirements
- Autothrottle Engine Pressure Ratio (EPR) trim - thrust balancing
- Condition monitoring - performance tracking
- Maintenance data - trouble shooting
- Primary display system data - indication.

14) Auxiliary Power Unit

The aircraft is fitted with an Auxiliary Power Unit (APU) - Model: GTCP 331-500 - manufactured by Allied Signal. The Allied Signal GTCP 331-500 gas turbine APU is a two-stage centrifugal flow compressor, a reverse flow annular combustion chamber and a three-stage axial flow turbine. It supplies the auxiliary power system for the aircraft pneumatic and electrical power. This permits independent operations from the ground external power sources or the main engines.

The APU generator supplies 120 KVA electrical power at any altitude. The APU can start at all altitudes up to the service ceiling of the aircraft (43,100 ft/13,100 m). Electrical power is available up to the service ceiling and pneumatic power is available up to 22,000 ft (6,700 m).

The ELMS contains the APU autostart logic and sends signal to the APU Controller (APUC).

The APU Controller serves to control the APU functions for:

- Starting and ignition
- Fuel metering
- Surge control
- Inlet guide vane (IGV) control
- Data storage
- Protective shutdown
- BITE/Fault reporting

- APU indication

The APU is designed to automatically start when certain logic conditions are met when the aircraft is in the air or electrical power removed from left and right transfer buses from respective No. 1 and No. 2 engine generators.

15) Communications

For Communications Systems description, refer to *Section 1.9*.

1.6.9 Aircraft Performance

The detailed Boeing Performance analysis of the aircraft is provided in *Appendix 1.6E.* This section summarises the aircraft performance and range capability of MH370.

The following data were available to help analyse the possible flight paths of the aircraft: ACARS data, radar data, and satellite data. Wind data were incorporated along the paths to determine the true airspeed which was incorporated into the performance fuel burn and range analysis.

The ACARS data provided the quantity of fuel on board after approximately 25 minutes of flight following take-off from KUL.

The radar data provided information about the flight path and ground speed after the last ACARS transmission and captured the left turn off of the scheduled route until the data ended over the Straits of Malacca. The analysis of the radar data allowed for an estimation of the fuel burn during that portion of the flight. However, that estimation was built on many assumptions, including flying at constant altitude and constant airspeed during each flight segment.

The satellite data provided evidence that the satellite was in communication with the aircraft until the last transmission at time 0019:29.42 UTC, approximately 7 hours and 37 minutes after take-off from KUL. Refer to *Section 1.9.5*.

The performance range capability of the aircraft, along with the satellite data, allowed for the creation of multiple flight path profiles that demonstrate that the aircraft had the range capability to reach the 7th Arc[10].

[10] Arcs - Lines created along the earth representing a set of possible aircraft positions at the time of satellite communication based on Burst Timing Offset (BTO). Refer to *Appendix 1.6E* for further details.

Many assumptions were also made during the flight path profile creation, including but not limited to, constant altitude and constant speed from Arc 1 to Arc 7, with the restriction that there were no course changes between the arcs. Additional analyses were conducted in Boeing and MAS simulators that continued the analysis after fuel exhaustion and assumed no intervention in the cockpit.

The results of the simulator session showed that the aircraft would roll gently to the left due to residual rudder deflection commanded by the Thrust Asymmetry Compensation (TAC) with the end of flight occurring within a 100 nm^2 box that extended 10 nm beyond fuel exhaustion and 10 nm to the left of the flight path. The maximum range after dual engine flame-out would have been achieved through driftdown, with manual control keeping the aircraft in wings level flight, and would extend the range of the aircraft by approximately 120 nm beyond the location of the dual engine flame-out.

1.6.10 Boeing Patent on Remote Control Take-over of Aircraft

There have been speculations that MH370 could have been taken over control remotely in order to foil a hijack attempt. Some of these speculations have mentioned a US patent that Boeing filed for in February 2003 and received (US 7,142,971 B2) in November 2006 for a system that, once activated, would remove all controls from pilots and automatically fly and land the aircraft at a predetermined location.

According to the patent, existing preventative measures such as bullet-proof doors and the carriage of air marshals on board may have vulnerabilities. The flight crew could decide to open a lockable bullet-proof cockpit door [refer to *Section 1.6.8, para. 4*)] and air marshals, if used, might be over-powered. In light of the potential that unauthorised persons might be able to access the flight controls of an aircraft, the inventors conceived of a technique to avoid this risk by removing any form of human decision process that may be influenced by the circumstances of the situation, including threats or violence on-board.

The 'uninterruptible' autopilot envisioned by the patent could be activated, either by pilots, on-board sensors or remotely via radio or satellite links by the airline or government agencies if there were attempts to forcibly gain control of the cockpit. This system once activated would disallow pilot inputs and prevent anyone on-board from interrupting the automatic take-over. Thus, the personnel on-board could not be forced into carrying out the demands of any unauthorised person(s). To make it fully independent, the system described in the patent would have its own power supply, inaccessible in-flight, so that it could not be disengaged by tripping circuit breakers accessible on-board the aircraft. The aircraft would remain in automatic mode until after landing when ground crew working in conjunction with authorised personnel would be called to disengage the system.

Boeing has confirmed that it has not implemented the patented system or any other technology to remotely pilot a commercial aircraft and is not aware of any Boeing commercial aircraft that has incorporated such technology. The technology was never installed on an aircraft.

It should also be noted that the aircraft 9M-MRO was delivered in May 2002 to MAS before the patent was issued in 2006. The aircraft was under the control of MAS for the entire time after delivery except for a short duration at Pudong, Shanghai Airport, China in August 2012, when it underwent wing tip repair by Boeing [refer to *Section 1.6.4, para. 2*)]. Even then the repair was under the oversight of MAS engineers. Aircraft modification installation data do not indicate that any systems like that described in the patent were installed on the aircraft post delivery and during in-service. Airworthiness protocols require that all modifications are approved for installation and a record kept of each modification incorporated. There is no reason to believe any systems like that described in the patent either were or could have been incorporated without the knowledge of MAS.

From the foregoing, there is no evidence to support the belief that control of the aircraft 9M-MRO (operating as MH370) could have been or was taken over remotely as the technology was not implemented on commercial aircraft.

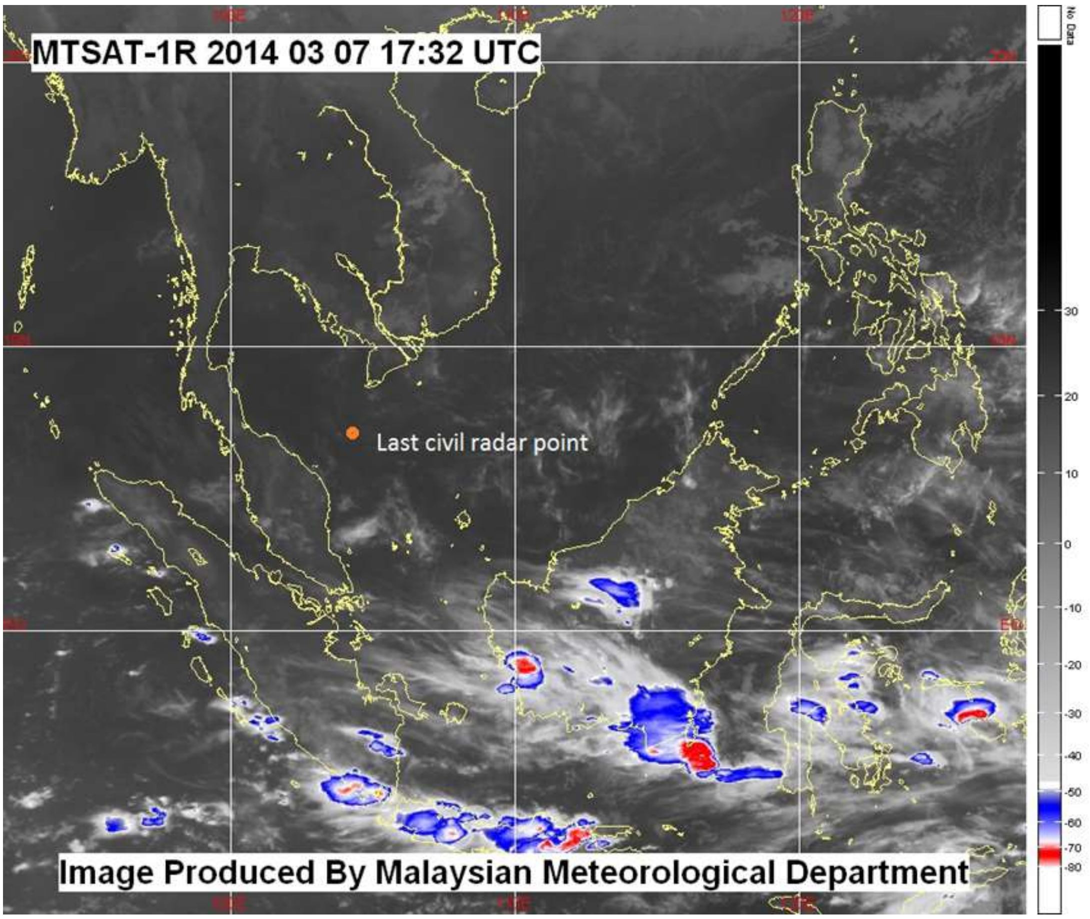
SECTION 1 – FACTUAL INFORMATION

1.7 METEOROLOGICAL INFORMATION

1.7.1 Meteorological Situation

Climatologically for the month of March, the position of the sub-tropical high is located over the Gulf of Thailand. The weather is generally dry with very little clouds. The winds are generally light from the surface to the height of 40,000 ft above sea level.

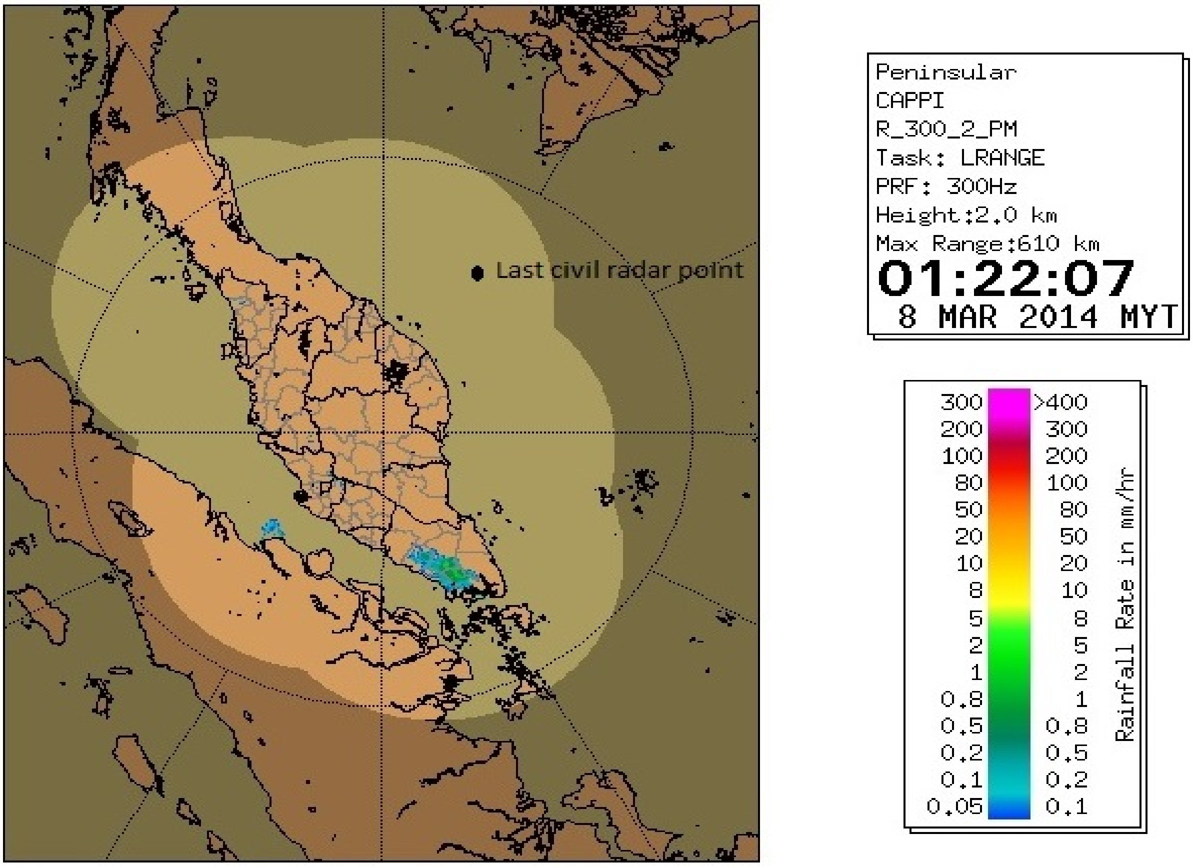
The infra-red image taken by the geostationary satellite Multifunctional Transport Satellites (MTSAT) 1R of Japan Meteorological Agency (JMA) at 1732 UTC 07 March 2014 [0132 MYT 08 March 2014] *(Figure 1.7A* [below]*)* showed that there were no significant clouds at the last civil radar point at 1722 UTC, 07 March 2014 [0122 MYT, 08 March 2014].



Source: Malaysian Meteorological Department

Figure 1.7A - Infrared Satellite image taken by MTSAT at 1732 UTC 07 March 2014 [0132 MYT, 08 March2014]

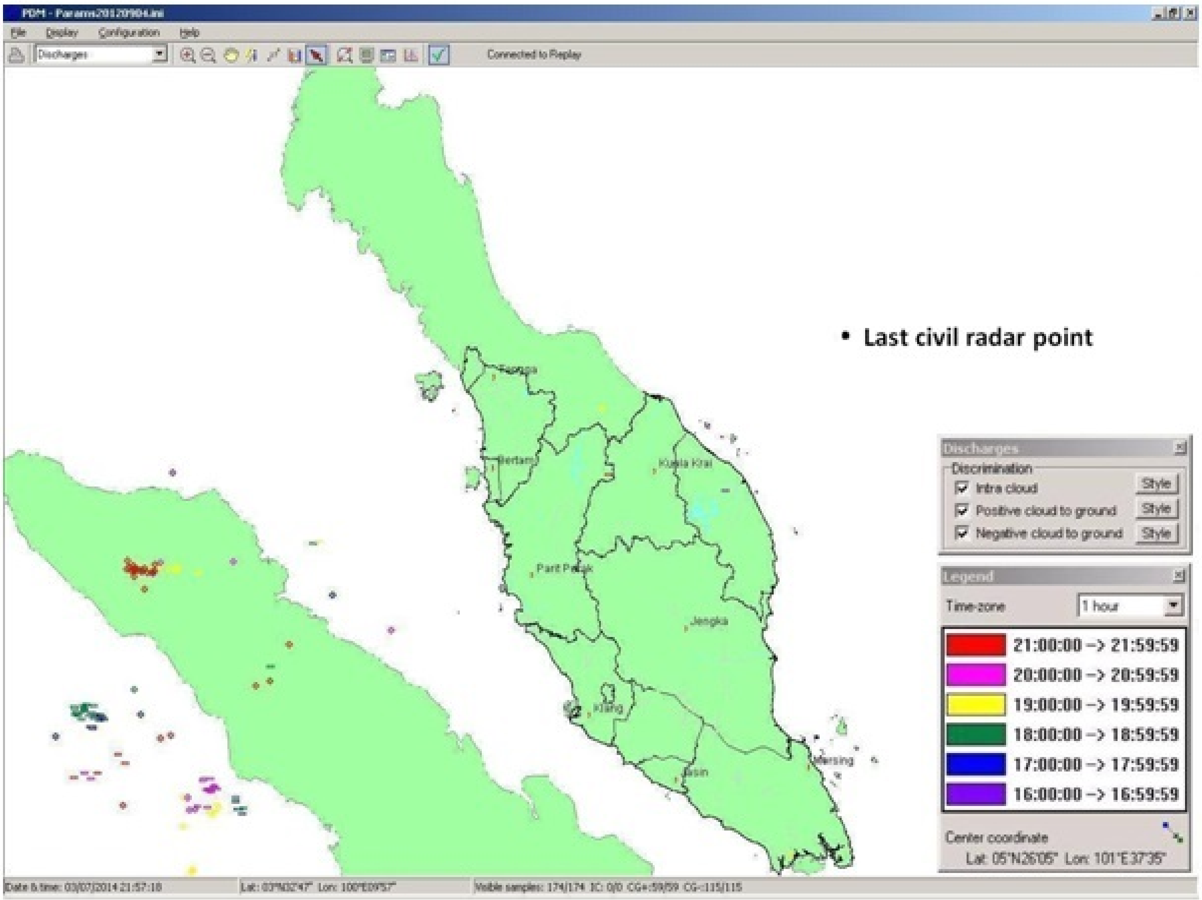
The meteorological radar image taken at 1722 UTC, 07 March 2014 [0122 MYT, 08 March 2014] (*Figure 1.7B* [below]) showed that no rain occurred at the last civil radar point.



Source: Malaysian Meteorological Department

Figure 1.7B - Meteorological Radar Image at 1722 UTC 07 March 2014 [0122 MYT, 08 March 2014]

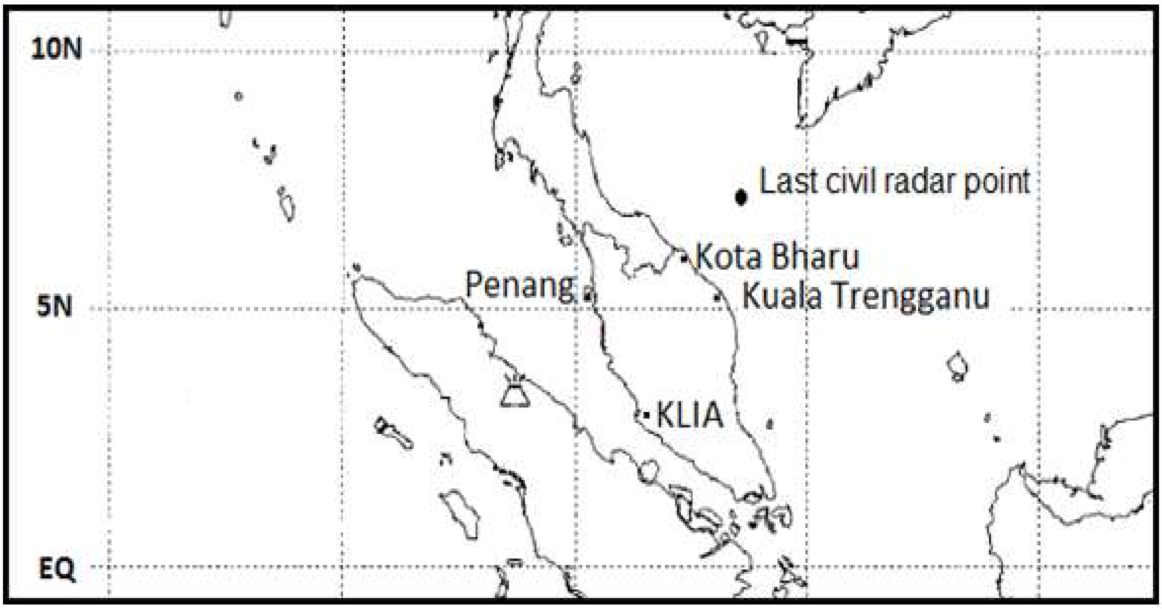
No lightning discharges were detected by the Lightning Detection System of the Malaysia Meteorological Department at the vicinity of last civil radar point from 1600 to 2159 UTC, 07 March 2014 [0000 to 0559 MYT, 08 March 2014]. *Figure 1.7C* (below) *Blue symbol* shows the lightning detected 1700 UTC to 1800 UTC, 07 March 2014 [0100 to 0200 MYT, 08 March 2014].



Source: Malaysian Meteorological Department

Figure 1.7C - Lightning Detection Map from 1600 to 2159 UTC 07 March 2014 [0000 to 0559, 08 March 2014]

The Meteorological Aerodrome Report (METAR) issued at 1600, 1700 and 1800 UTC [0000, 0100 and 0200 MYT, 08 March 2014] from Kota Bharu Sultan Ismail Petra Airport (WMKC), Kuala Terengganu Airport (WMKN), Penang International Airport (WMKP) and KLIA (WMKK) (*Figure 1.7D* [below]) did not report any significant weather phenomena.



Source: Malaysian Meteorological Department

Figure 1.7D - Locations of METAR Reports

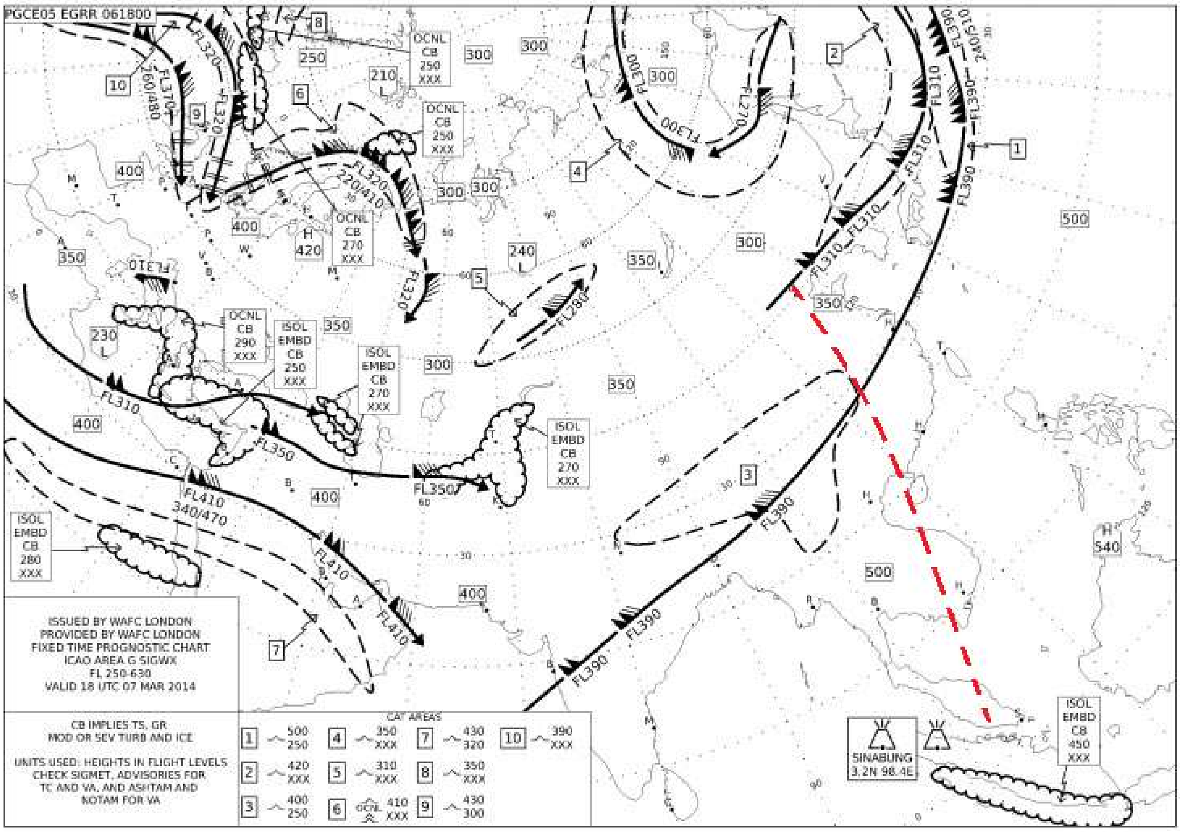
There was no direct observation of the wind conditions at the last civil radar point, the closest upper air observation was at the Kota Bharu Meteorological Station, taken at 1200 UTC, 07 March 2014 and at 0000 UTC, 08 March 2014 [2000 MYT, 07 March 2014 and 0800 MYT, 08 March 2014] respectively, both reported a temperature of -40ºC and wind from the north-east at 15 kt or less at 36,000 ft above sea level.

1.7.2 Comments on the Information Available

1) Forecast Charts

a) Significant Weather Chart

The Significant Weather Chart (SIGWX) *PGCE05 EGRR 061800* issued by World Area Forecast Centre (WAFC) London Fixed Time Prognostic Chart ICAO Area G SIGWX for FL250-630 (25,000 ft to 63,000 ft above standard sea-level pressure) valid 1800 UTC, 07 March 2014 [0200 MYT, 08 March 2014] showed that the filed flight plan route (red dotted line - *Figure. 1.7E* [below]) passed through a westerly jet stream with wind speed of up to 150 kt at latitude 30°N at FL390. Another westerly jet stream with wind speed of up to 100 kt at FL310 at the destination. Light clear air turbulence (CAT) might be expected from 25°N onwards to the destination. However, no significant adverse weather phenomenon was expected for the whole planned flight route.



Source: WAFC London

Figure 1.7E - Significant Weather Chart PGCE05 Issued by WAFC London Fixed Time ICAO Area G Prognostic Chart SIGWX FL250-630 valid 1800 UTC, 07 March 2014 [0200 MYT, 08 March 2014

b) Wind and Temperature Forecast Chart

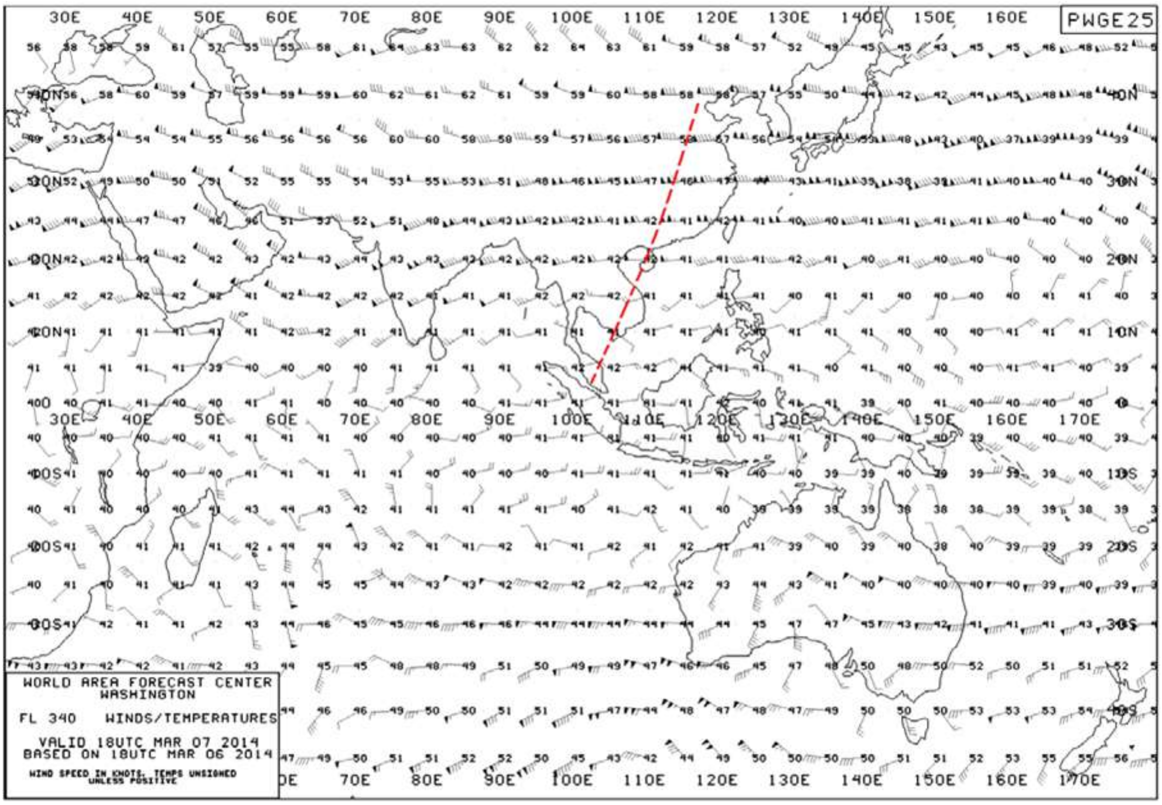
The wind and temperature forecast chart PWGE25 for FL340 valid 1800 UTC, 07 March 2014 issued by WAFC Washington showed the jet stream as in the significant weather chart above. The forecast winds at the last civil radar point and last air defence radar point were below 20 kt *(Figure 1.7F* [below]).

2) Significant Meteorological Information

Significant Meteorological Information (SIGMET) 3 was issued for the GUANGZHOU FIR valid from 12:45 to 16:45 UTC, 07 March 2014 [0200 MYT, 08 March 2014] indicated a thunderstorm forecast north of latitude 27°N and moving eastwards at 50 km/h in the layer with cloud tops at FL260.

3) Volcanic Ash Advisory

Volcanic ash advisories issued by Darwin Volcanic Ash Advisory Centre (VAAC) on 07 March 2014 at 06:27 and 18:37 UTC [2045 MYT, 07 March 2014 and 0045 MYT, 08 March 2014] for Sinabung (Sumatra, Indonesia) highlighted volcanic eruption located at 3.10°N 98.23°E (*Figure 1.7E* [above]*)* and volcanic ash plume observed up to FL120 and the plume was extending toward the west.



Source: WAFC Washington

Figure 1.7F - The wind and temperature forecast chart PWGE25 issued by WAFC Washington for FL340 valid 1800 UTC 07 March 2014 [0200 MYT, 08 March 2014]

1.7.3 Availability of Meteorological Information

The necessary meteorological information was made available to the crew.

SECTION 1 – FACTUAL INFORMATION

1.8 AIDS TO NAVIGATION

Not applicable.

SECTION 1 – FACTUAL INFORMATION

1.9 COMMUNICATIONS

1.9.1 High Frequency System

This aircraft was installed with Collins HFS-900 High Frequency (HF) System. The HF communication system on this aircraft uses two HF systems with a common HF antenna to transmit and receive radio frequency (RF) signals in the HF range.

The HF transceiver operates within the frequency range of 2,000 MHz to 29,999 MHz and one KHz channel spacing.

The Left Transfer bus sends 115V AC three-phase power to the Left HF communication system. The Left HF communication transceiver supplies 115V AC single phase to the Left HF antenna coupler for operational power. It also supplies 28V DC for the key interlock function. The Right HF communication system is the same as the Left, except that it uses power from the Right AC Sec 2 bus.

1.9.2 Very High Frequency System

This aircraft was installed with Collins VHF-900B VHF System. The very high frequency (VHF) communication system permits voice and data communication over line-of-sight distances. It permits communication between aircraft or between ground stations and aircraft. The VHF system operates in the VHF aeronautical frequency range of 118.000 MHz to 136.992 MHz.

The VHF communication system on this aircraft uses three VHF systems. Each VHF system has a VHF antenna and a VHF communication transceiver.

The VHF communication system connects with Selective Calling Equipment (SELCAL) decoder that starts an alert when a call comes in for that aircraft.

The captain's flight instrument bus sends 28V DC to the Left VHF communication transceiver and the Left Radio Tuning Panel (RTP). The Left Main DC bus sends 28V DC to the centre VHF communication transceiver and the centre RTP.

The Right Main DC bus sends 28V DC to the right VHF communication transceiver and the right RTP.

1.9.3 Air Traffic Control/Mode S Transponder System

This aircraft was installed with a Bendix/King TRA-67A Mode S transponder. The Air Traffic Control (ATC) ground stations interrogate the airborne ATC/Mode S transponder system as shown in *Figure 1.9A* (below).

The ATC/Mode S transponder replies to the interrogations in the form of coded information that the ground station uses. The ground station uses a Primary Surveillance Radar (PSR) to get radar returns from aircraft within the radar range. To make a communication link with the aircraft in the radar range, the ground station uses a Secondary Surveillance Radar (SSR) to interrogate the ATC/Mode S transponder. The ground station transmits a side lobe suppression signal to inhibit close ATC replies that come from a SSR side lobe transmission.

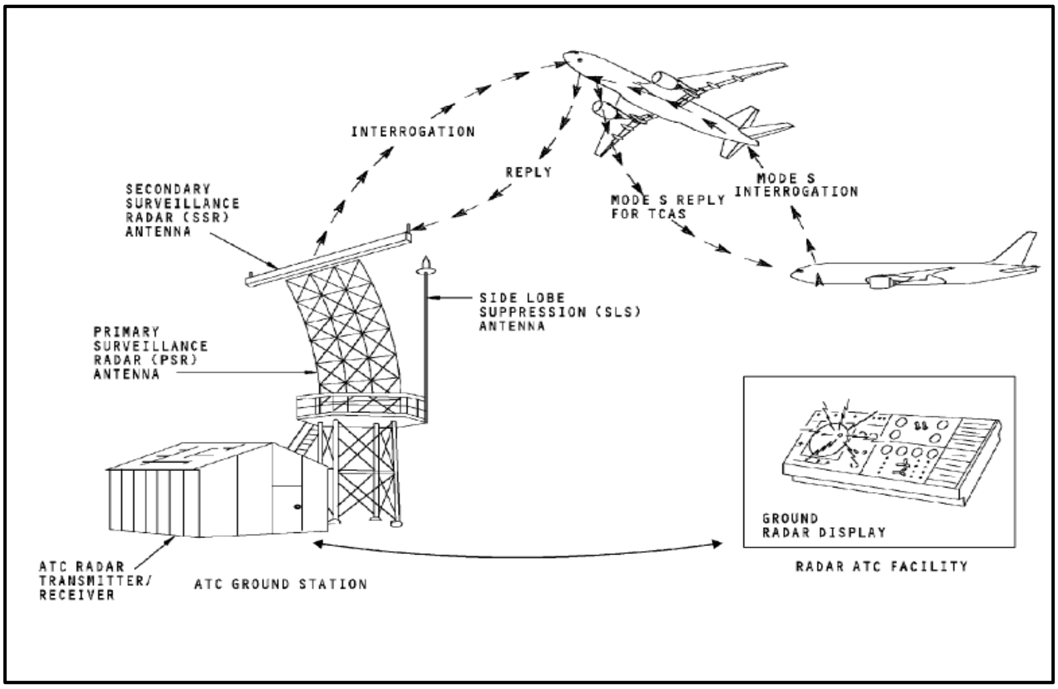


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Figure 1.9A - Air Traffic Control/Mode S Transponder System

On the ground radar display, the Air Traffic Controller (ATC) sees the radar returns, altitude, and a four digit aircraft identifier. The ATC also sees aircraft derived Enhanced Surveillance downlink data on the ground station radar display, such as Magnetic Heading, Air Speed (Indicated Air Speed and Mach number), Ground Speed, Roll Angle, Selected Altitude, True Track Angle, and Vertical Rate.

The ATC/Mode S transponder also replies to mode S interrogations from the Traffic Alert and Collision Avoidance Systems (TCAS) of other aircraft. ATC/Mode S transponders with Extended Squitter function provide broadcast of Global Position System (GPS) position and velocity data.

Two transponders are installed on the aircraft. A Transponder selector switch on the Transponder panel in the cockpit allows selection of either the left or the right transponder. During normal operations the crew procedure is to leave the left transponder selected on the panel. There is no automatic switching between the transponders if one fails. It must be done manually by the pilots. Failure of either of the transponders will be annunciated in the cockpit. The Left ATC/Mode S transponder gets 115V AC power from the AC Standby bus. The Right ATC/Mode S transponder gets 115V AC power from the Right AC Transfer bus. The dual transponder panel gets 115V AC power from the AC Standby bus. The two transponders are powered by highly reconfigurable AC buses; the left one can be powered by the battery if the left AC bus is unavailable (the AC Standby bus can be powered by the left Transfer bus or the battery), and the AC Transfer busses also have their alternate sources.

This system can be deactivated (turned OFF) by pulling the circuit breakers located at the P11 overhead circuit breaker panel or by selecting the Transponder Mode Selector (Transponder Panel) to “STBY” position. The transponder on the occurrence flight was operating satisfactorily up to the time it was lost on the ATC radar screen at 1721.13 UTC, 07 March 2014 [0121:13 MYT, 08 March 2014]. There was no message received from the aircraft to report a system failure.

1.9.4 Aircraft Communications Addressing and Reporting System

The Aircraft Communications Addressing and Reporting System (ACARS) is a digital data-link system that manages flight plan and maintenance data between the aircraft and the Ground Service Provider (GSP) by using radio i.e. VHF or satellite communications (SATCOM) as shown in *Figure 1.9B* (below).

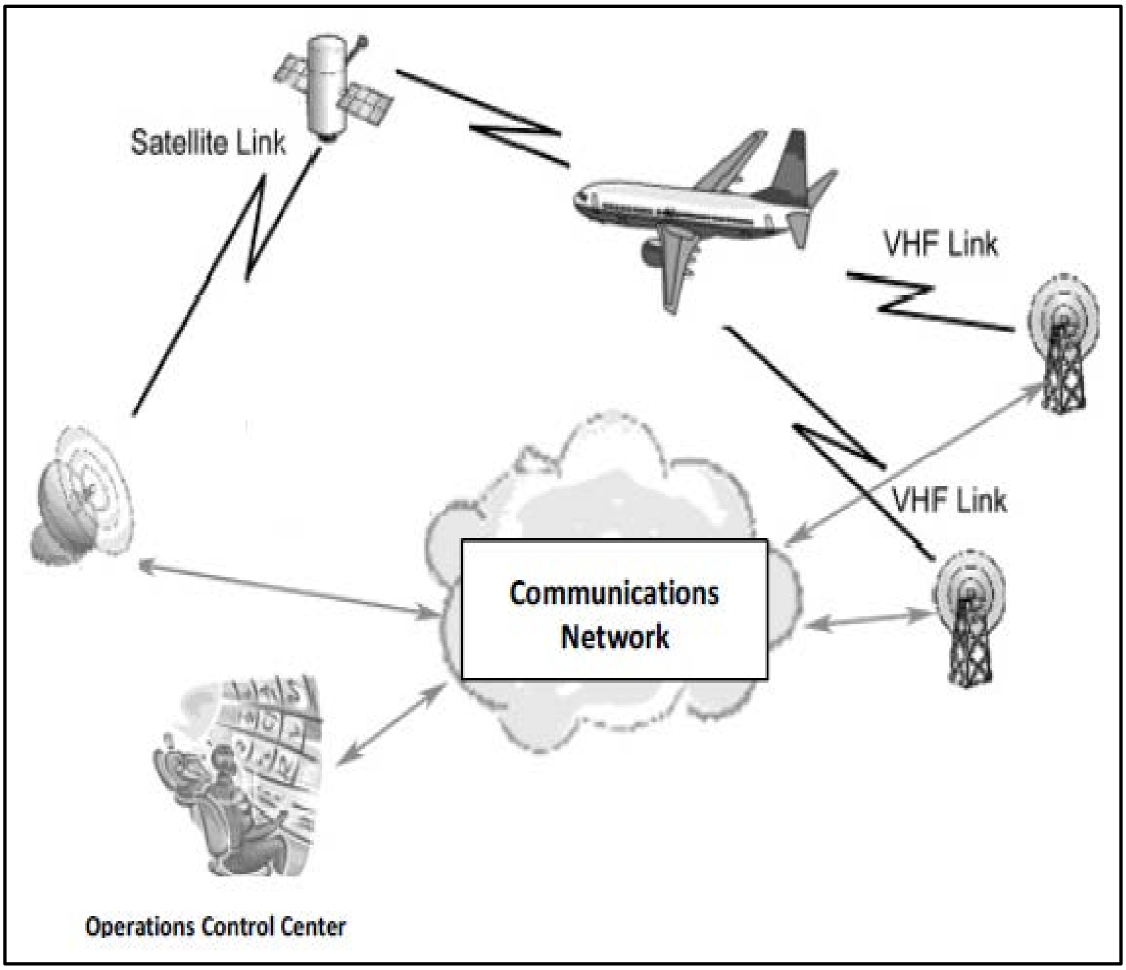

Figure 1.9B - ACARS System

ACARS provides message communication between aircraft and its base (ground). The following messages are transmitted:

- **O**ut of the gate, **O**ff the ground, **O**n the ground, and **I**nto the gate (OOOI) events:
  - **O**ut of the gate event: Departure from the gate with all doors closed and parking brake released;
  - **O**ff the ground event: Take-off with the nose gear squat switch extended;
  - **O**n the ground event: Touch down with the nose gear squat switch compressed; and
  - **I**nto the gate event**:** Parked at the gate with the parking brake set and the door open.

- Flight plans: ACARS interfaces with Flight Management Systems (FMS) acting as the communication system for flight plans to be sent from the ground to the FMS. This enables the aircraft to update the FMS while in flight and allows the flight crew to evaluate the alternative flight plans including the status of connecting flights.

- Weather information: ACARS interfaces with FMS, acting as the communication system for weather information to be sent from the ground to the FMS. This enables the aircraft to update the FMS while in flight and allows the flight crew to evaluate new weather conditions.

- Equipment health: ACARS is used to send information from the aircraft to ground stations about the conditions of various aircraft systems and sensors in real-time. Maintenance faults and abnormal events are also transmitted to ground stations along with detailed messages, which are used by MAS for monitoring equipment health, and to better plan the repair and maintenance activities.

- Aircraft positions which provide latitude and longitude, altitude, speed, total air temperature, total remaining fuel, wind direction and speed and heading.

- Engine performance data which provide engine data during take-off, climb, cruise and approach.

ACARS interfaces with the Multifunction Display (MFD) in the cockpit, which flight crew can use to send and receive technical messages and reports to or from ground stations, such as a request for weather information or clearances or the status of connecting flights. The response from the ground station is received on the aircraft via ACARS as well. The ACARS Manager page in the Communications main menu on the selected Multifunction Display (MFD) is used for this purpose. The COMM display switch, located on the display select panel, displays the communications main menu on the selected MFD. The ACARS Manager page allows the flight crew to independently select/deselect VHF or SATCOM transmission of data.

The ACARS communicates through either the VHF or the SATCOM systems. The ACARS datalink connects to the Satellite Data Unit (SDU) of the SATCOM system and the Center and Right VHF Communication Transceivers of the VHF systems. The Center VHF exchanges data with the ACARS modem in the Communications Core Processor Module (CPM/Comm) of the Left AIMS cabinet. The right VHF exchanges data with the ACARS modem in the CPM/Comm of the Right AIMS cabinet. The ACARS does not interface with the Left VHF Transceiver.

For the ACARS operation the Data Communication Management Function (DCMF) of the AIMS uses the voice/data select to set the VHF Communication Transceiver to the data signal mode. At power-up, the DCMF sets the Center VHF Communication Transceiver to the data signal mode. If the Center VHF Communication Transceiver fails, or voice is selected manually by the flight crew, the DCMF selects SATCOM for data transmissions. If SATCOM fails, the DCMF selects the Right VHF Communication Transceiver for data transmissions. The Left VHF Communication Transceiver is voice only. On the event flight, as instructed by Ground Operations via text message shown on the MFD (shown as 'Switch VHF3 to Voice'), the flight crew would have selected voice on the Center VHF resulting in SATCOM being used for the data transmissions. Refer to page 1 of *Appendix 1.9A – ACARS Traffic Log*. The use of SATCOM for the ACARS transmissions is evident in the SATCOM Ground Station Logs [refer to *Section 1.9.5*, *para. 4*)]. This switching from VHF to SATCOM for the data transmissions is normal practice in MAS for commercial reasons.

In the event that the aircraft ACARS unit has been silent for longer than a pre-set time interval, the ground station can ping the aircraft (directly or via satellite). A ping response indicates a healthy ACARS communication. This ping is different from the Satellite ping or handshake.

Pre-set time interval for MAS B777 is 30 minutes. When the aircraft ACARS is silent for more than 30 minutes, MAS Operation Control Centre (OCC) is required to send a text message via ACARS to the cockpit or to call the cockpit via SATCOM.

1) Aircraft Communications Addressing & Reporting System Traffic Log

ACARS traffic log messages sent/received to/from 9M-MRO between 1554:41 UTC, 07 March 2014 [2354:41 MYT, 07 March 2014] until 1815:25 UTC, 07 March 2014 [0215:25 MYT, 08 March 2014] is shown in *Appendix 1.9A*. Some key events are extracted and explained below.

At 1554:41 UTC, 07 March 2014, ACARS data link was fully established on SATCOM transmission and at 1556:08 UTC the flight information (FI) MH0370 and Aircraft Number (AN) 9M-MRO were keyed in by the crew as per *Figure 1.9C* (below).

Figure 1.9C - ACARS data link established SATCOM transmission

Notice to Crew (NOTOC) was sent at 1606:15 UTC on 07 March 2014 [0006:15 MYT, 08 March 2014] direct to the aircraft printer and to be printed out by the crew.

NOTOC from the ground station to the cockpit stated the special loads of total 4,566 kg of mangosteens were carried on board. Details of the mangosteens were:

- 1,128 kg at station 41L,
- 1,152 kg at station 41R,
- 1,148 kg at station 43L, and
- 1,138 kg at 44L respectively.

(Refer to *Section 1.18.2* for details of cargo carried).

Declaration of *"there is no evidence that any damaged or leaking packages containing dangerous goods have been loaded on the aircraft at this station"* was also written in the NOTOC message. *Figure 1.9D* (below) shows the snapshot of the ACARS NOTOC message.

Aircraft final loadsheet was sent via ACARS at 1606:32 UTC, 07 March 2014 [0006:32 MYT, 08 March 2014] direct to the aircraft printer and to be printed out by the crew. Details of aircraft weight as stated in the final loadsheet are discussed in *Section 1.6.5*.

16:06:15 46818160 Outgoing Uplink 9M-MRO MH0370 MHKULKJACM001 071606 AGM RELAY

Uplink Sent AGM NOTOC Uplink B777 -- AGM NOTOC Uplink B77 QXSXMXS

```
QU QXSXMXS
.DPCCAMH 071606
□AGM
AN 9M-MRO/FI MH0370/MA 989I
-
NOTOC MESSAGE
SPECIAL LOAD NOTOC

FLIGHT   DATE        EDNO
MH 0370 /08  08MAR14  01
FROM/TO  AC/REG
KULPEK   9M-MRO

OTHER SPECIAL LOAD

TO  POS PCS QTY/TI IMP
DESCRIPTION
PEK 41L 001 1128KG PER
MANGOSTEEN

PEK 41R 001 1152KG PER
MANGOSTEEN

PEK 43L 001 1148KG PER
MANGOSTEEN

PEK 44L 001 1138KG PER
MANGOSTEEN

THERE IS NO EVIDENCE
THAT ANY DAMAGED OR
LEAKING PACKAGES
CONTAINING DANGEROUS
GOODS HAVE BEEN LOADED
ON THE AIRCRAFT AT THIS
STATION.

END ACARS NOTOC
```

Figure 1.9D - Snapshot of ACARS NOTOC message

Figure 1.9E (below) shows the snapshot of the final loadsheet of this aircraft.

```
16:06:32    381598235 Outgoing Uplink    9M-MRO    MH0370    MHKULKJACM001    071606    AGM    RELAY
Uplink Sent    Loadsheet FINAL <9M-MR> -- LOADSHEET - AGM(Pı QXSXMXS

QU QXSXMXS
.DPCCAMH 071606
□AGM
AN 9M-MRO/FI MH0370/MA 990I
-
X LOADSHEET FINAL  1606 01
MH0370/ 07MAR14
KUL PEK   9M-MRO   2/10
ZFW 174369 MAX 195044 L
TOF  49100
TOW 223469 MAX 286897
TIF  37200
LAW 186269 MAX 208652
UNDLD  20675
PAX/10/215       TTL 227
TTL 222/3/2
TTL COMPARTMENTS 014296
 1/2500 2/4530 3/804 4/5
885 5/577    0/0
SEATING
0A/10 0B/127 0C/88

DOI        59.07


LIZFW      67.05
MACZFW     31.65
LITOW      70.05
MACTOW     33.78

DLI        57.29
STAB TO    03.9 MID
SI:
NOTOC YES
TTL PAYLOAD 014296
DOW 143283

WBC K8-45
EXP 20SEP14
NOTOC - YES



-------------------------

PAX/10/215       TTL 227
TTL 222/3/2


0A/10 0B/127 0C/88


*--------------------------------------------*
* PLSE ACK WITH                              *
```

Final Loadsheet transmitted to aircraft Cockpit and directed to aircraft printer

Figure 1.9E - Final Loadsheet

Pilot acknowledgement and confirmation of the final loadsheet is shown in the ACARS snapshot in *Figure 1.9F* (below).

16:09:29	46818215	Outgoing Downlink	9M-MRO	MH0370	IOR2	MHKULKJACM001	071609	EMAILCNX
Ground Sent		B777 Final Loadsheet Acknowledgement -- B777 LS			mtb01mh@malaysiaairlines.com			

```
***FINAL LOADSHEET ACKNOWLEDGEMENT from PILOT*****
AIRCRAFT REGISTRATION       : 9M-MRO
Flight No                   : MH0370
Date                        : 07-03-2014
Time                        : 16:09 UTC
Departure Station           : KUL(WMKK)
Acknowledgement From Pilot : LS FINAL OK

PIC License No              :
751 KUL


****************END of MESSAGE******************
```

Confirmation from pilot that he has received the Loadsheet in human readable structure

Figure 1.9F - Final Loadsheet Acknowledgement

Data on aircraft APU is shown in *Figure 1.9G* (below). APU report generated by ACMS sent via ACARS at 1629:33 UTC stated the total APU cycles and hours were 15,699 cycles and 22,093 hours. APU hours for the previous flight was 4 hours.

16:29:33	46818489	Incoming Downlink	9M-MRO	MH0370	IOR2	MHKULKJACM001	071629	DFD	RELAY
Normal		B777 APU Report			QXSXMXS				

```
QU DPCCAMH
.QXSXMXS 071629
□DFD
FI MH0370/AN 9M-MRO
DT QXT IOR2 071629 D00A
-  MAS002A0          B777 APU OPS REPORT            332

ACID    FLT  FM FLCT   DATE      GMT    DPT  DST
MRO     S370 PO  318 07/03/14 16:29:12 WMKK ZBAA

     SWID         SFC
316A-BSM-710-02 17911

APU CYC    APU TOT HRS  APU PREV FLT HRS
 15699        22093               4
```

Figure 1.9G - APU Report

Engine take-off and climb reports transmitted via ACARS are explained in *Section 1.6.4 para. 8*). Engine parameter reports were transmitted to MAS and then to Rolls Royce for Engine Health Monitoring (EHM). *Appendix 1.9A* shows these data in coded form. The decoded data are shown in *Appendix 1.6B*.

The first (which was also the last) position report was transmitted via ACARS at 1707:29 UTC, 07 March 2014 [0107:29 MYT, 08 March 2014]. This was a collation of 6 reports generated at 5-minute intervals by the system at 1641:43 UTC, 1646:43 UTC, 1651:43 UTC, 1656:43 UTC, 1701:43 UTC and 1706:43 UTC, 07 March 2014. Parameters transmitted are as per *Table 1.9A* (below). The actual traffic log on the position report is reproduced in *Figure 1.9H* (below). Position reports were programmed to be transmitted every 30 minutes.

Note:

Aircraft position information is also included in the EHM take-off and climb reports.

Greenwich Mean Time (GMT) - UTC	**1641:43**	**1646:43**	**1651:43**	**1656:43**	**1701:43**	**1706:43**
Altitude (ALT) – Feet	103	10,582	21,193	28,938	34,998	35,004
Calibrated Airspeed (CAS) - Knots.	168.4	261.8	301.1	303.1	278.0	278.4
MACH	0.255	0.478	0.669	0.783	0.819	0.821
Total Air Temperature (TAT) - °C	31.1	23.4	11.6	2.5	-13.4	-13.1
Static Air Temperature (SAT) - °C	27.3	10.4	-11.8	-27.4	-43.9	-43.8
Latitude (LAT)	2.667	3.074	3.553	4.109	4.708	5.299
Longitude (LONG)	101.715	101.760	01.988	102.251	102.434	102.713
Gross Weight (GWT) – lb	492,520	489,200	486,240	483,840	481,880	480,600
Total Remaining Fuel Weight (TOTFW) - kg	49,200	47,800	46,500	45,400	44,500	43,800
Wind Direction (WINDIR)	140.3	107.6	1.8	58.4	69.6	70.0
Wind Speed (WINDSP)	1.25	9.38	19.50	10.63	17.38	17.13
True Heading (THDG)	-33.5	27.7	27.8	26.0	26.8	26.7

Table 1.9A - ACARS Position Report

```
17:07:29  46818992  Incoming Downlink  9M-MRO  MH0370  IOR2  MHKULKJACM001  071707  DFD  RELAY
Normal              DFD B777 Position Report (NEW)          QXSXMXS

QU DPCCAMH
.QXSXMXS 071707
□DFD
FI MH0370/AN 9M-MRO
DT QXT IOR2 071707 D03A
-  MAS001A0          B777 POSITION REPORT           565

ACID   FLT  FM FLCT   DATE    DPT  DST
MRO    S370 TR  318 07/03/14 WMKK ZBAA

     SWID         SFC
316A-BSM-710-02 18661

 GMT    ALT    CAS  MACH  TAT   SAT     LAT     LONG
164143    103 168.4 .255  31.1   27.3   2.767  101.715
164643  10582 261.8 .478  23.4   10.4   3.074  101.760
165143  21193 301.1 .669  11.6  -11.8   3.553  101.988
165643  28938 303.1 .783   2.6  -27.4   4.109  102.251
170143  34998 278.0 .819 -13.4  -43.9   4.708  102.534
170643  35004 278.4 .821 -13.1  -43.8   5.299  102.813

 GWT   TOTFW  WINDIR WINDSP  THDG
492520  49200  140.3   1.25  -33.5
489200  47800  107.6   9.38   27.3
486240  46500   91.8  19.50   27.8
483840  45400   58.4  10.63   26.0
481880  44500   69.6  17.38   26.8
480600  43800   70.0  17.13   26.7

18:03:23  46819784  Outgoing Uplink  9M-MRO  MH0370  MHKULKJACM001  071803  AGM  RELAY
```

Figure 1.9H - Position Report

The first message sent to the aircraft cockpit printer from the MAS ODC was at 1803:23 UTC. The ACARS message requested the crew to contact the HCM ACC immediately. The incoming downlink message at 1803:24 UTC showed the message failed to reach the aircraft. Messages are auto transmitted every 2 minutes and the message was retransmitted until 1843:33 UTC but all messages failed to get a response. Automated downlink message by ACARS showed 'failed'. Message sent to the aircraft cockpit printer and the Automated Downlink messages are shown in *Figures 1.9I* and *1.9J* (below), respectively.

```
18:03:23    46819784    Outgoing Uplink    9M-MRO    MH0370    MHKULKJACM001    071803    AGM    RELAY
Uplink Sent             B777 Cockpit Printer Uplink for ODC -- B777 Cockpit QXSXMXS

QU QXSXMXS
.DPCCAMH 071803
□AGM
AN 9M-MRO/FI MH0370/MA 991I
-
=======================================
| MALAYSIA AIRLINES - ODC              |
=======================================
URGET REQUEST

PLS CONTACT HO CHI MING ATC ASAP

THEY COMPLAIN CANNOT TRACK YOU ON THEIR RADAR

I RECEIVED CALL FROM SUBANG CENTRE

PLS ACK THESE MSG

REGARDS
```

Figure 1.9I - Message from MH ODC

```
18:06:25    46819784    Incoming Downlink    9M-MRO    MH0370    MHKULKJACM001    071806    MAS    RELAY
Normal                  MAS-F (failed)                 QXSXMXS
```

Figure 1.9J - Automated Downlink Message

1.9.5 Satellite Communications

1) Satellite Communications System Description

Satellite Communications (SATCOM) is an acronym of, and generic term for, satellite communications. SATCOM operates by using satellites to relay radio signals between the sender and receiver. It can cover far more distance and wider areas than other radios. SATCOM can be used to transmit words, pictures and other forms of information.

The aircraft, 9M-MRO, was equipped with a SATCOM terminal that used the Inmarsat Classic Aero system. The Inmarsat system utilises a constellation of satellites to provide nearly global coverage, the exception being polar areas. The aircraft SATCOM system, also referred to as an Airborne Earth Station (AES) operates on L Band, transmits at 1.6 GHz and receives at 1.5 GHz. For this aircraft, the

SATCOM system provided a total of five voice channels and one data channel. The satellite link provides the following functions:

- Audio and text communication;
- ACARS data; and
- In-flight Entertainment (IFE) Equipment connectivity.

The Earth or Ground Station uses C Band, transmits at 6 GHz and receives at 4 GHz. Inmarsat uses a network of Ground Earth Stations (GES) to communicate with the satellites and connect the SATCOM signal to other terrestrial data networks such as telephone systems, internet, etc.

When the SATCOM AES is first powered on, it sends a log-on request to the GES to initiate service.

There are a number of channels available for messages to be sent between the Satellite and Earth Station. One of the channels is called the 'common access channel', which aircraft will constantly listen to when able to do so.

If the GES has not heard from an aircraft for an hour after the last communication, it automatically transmits a 'log on interrogation' ("ping") message on the common access frequency using the aircraft's unique identifier. If the aircraft receives its 'unique identifier', it returns a short message that it is still logged onto the network. Both the initial log-on request and the hourly ping have been termed as a 'handshake'.

The SATCOM AES consists of the following equipment: Radio frequency unit (RFU), Radio frequency attenuator (RF ATTN), Radio frequency splitter (RFS), Class C high power amplifier (HPA), Class A high power amplifier (HPA), High power relay (HPR), three low noise amplifier/diplexers (LNA/DIPs), Low gain antenna (LGA), two beam steering units (BSUs), two high gain antennas (HGAs), Radio frequency combiner (RFC) and Satellite data unit (SDU).

The SATCOM avionics are located on the E11 rack, which is in the crown area aft of doors 3 left/right. The High Gain antennas are mounted above door 3 left and door 3 right. The Low Gain antenna is mounted on the fuselage centreline. The SATCOM Circuit Breakers (CB) are located in the Main Equipment Center (MEC).

The Satellite Data Unit (SDU) receives 115V AC from the Left Main bus. In flight, this bus can be powered by engine mounted generators or the APU generator. Neither the aircraft battery nor the ram air turbine will power the SATCOM system.

The diagram in *Figure 1.9K* (below) shows the complete set of SATCOM units, including avionics, High Gain Antenna Subsystem and Low Gain Antenna Subsystem. It also shows interfaces to the aircraft cockpit and cabin systems and functions. The following notes are intended to be read in conjunction with *Figure 1.9K* (below)*:*

a) CDU (3) are the three Control Display Units, otherwise known as Multi-function Control Display Units (MCDUs).

b) CPMU is Cabin Passenger Management Unit, which provides an interface between the Panasonic IFE and the SDU, for any Data-3 SMS/e-mail messages.

c) AMU is the Audio Management Unit, which feeds cockpit audio to and from the SDU.

d) CTU is the Cabin Telecommunications Unit, which provides an interface between the in-seat handsets and the SDU, for cabin telephony calls, were that functions available. In the case of 9M-MRO, the in-seat phones can only be used for seat-to-seat calling.

e) AIMS Cabinet is one of two Airplane Information Management System cabinets, which route numerous information to and from the SDU, including ACARS data, Navigational data, AES ID and Flight ID.

f) SATCOM Maintenance Switch is not relevant to this document, as no maintenance activity is possible in flight.

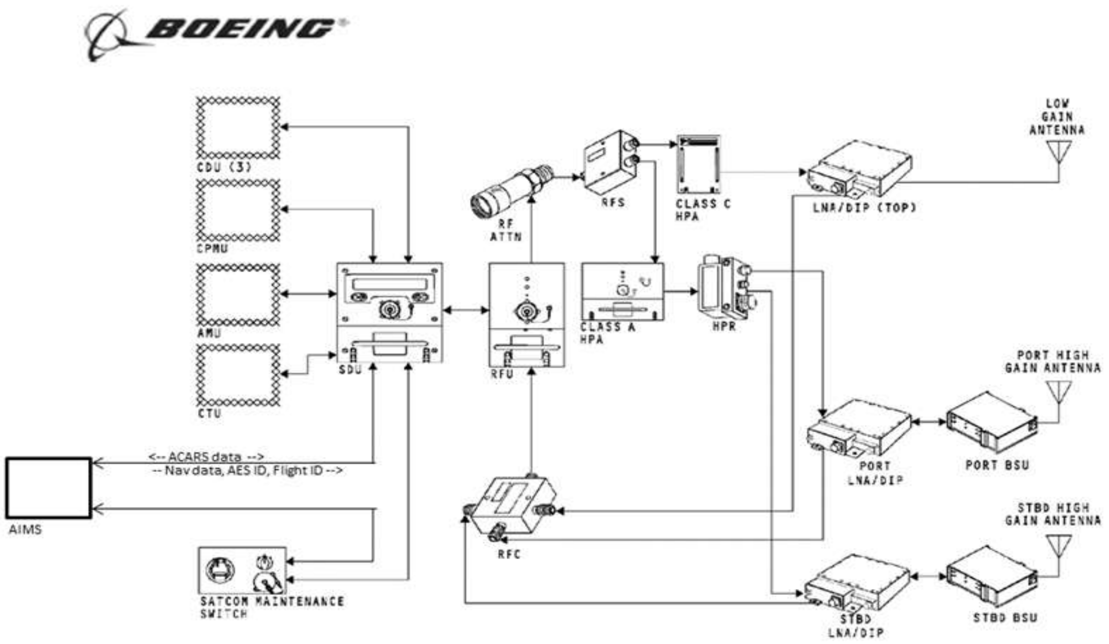

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Figure 1.9K - SATCOM System

The photo in *Figure 1.9L* (below) shows the Honeywell/Racal (Honeywell/Thales) MCS-6000 SATCOM Units - RFU (left), SDU (centre) and HPA (right).

Figure 1.9L - RFU (left), SDU (centre) and HPA (right)

2) Satellite Communications Ground Station Logs of the Event - Introduction

Throughout the flight of MH370, the aircraft communicated through the Inmarsat Indian Ocean Region (IOR) I-3 Satellite and the GES in Perth, Australia.

Figure 1.9M (below) shows the Inmarsat I-3 IOR Satellite Coverage Map. The blue lines represent the elevation angle to the IOR satellite for a SATCOM unit on the ground or in the air. Due to the satellite inclination, the elevation angles are approximate.

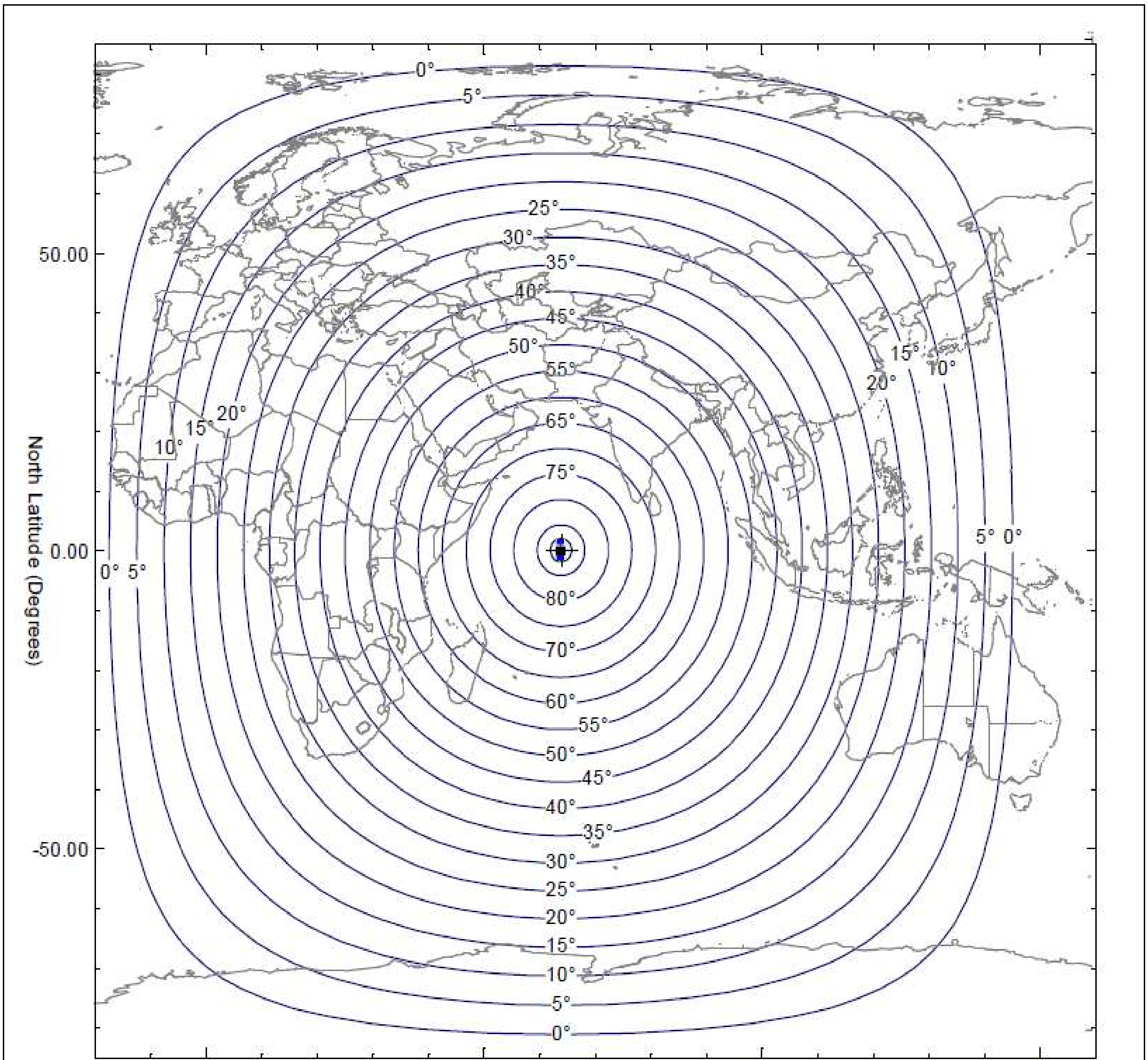

Figure 1.9M - Inmarsat I-3 IOR Satellite Coverage Map

MH370 departed KLIA at 1642 UTC [0042 MYT, 08 March 2014]. At 1707 UTC, the SATCOM system was used to send a standard ACARS report, normally sent every 30 minutes. The message also indicated the remaining fuel on-board.

The ACARS reports expected at 1737 UTC and 1807 UTC were not received. The next SATCOM communication was a log-on request from the aircraft at 1825 UTC. From that point until 0011 UTC, SATCOM transmissions indicate that the link was available, although not used for any voice, ACARS or other data services apart from two unanswered ground-to-air telephone calls. At 0019 UTC, the AES initiated another log-on request. The log-on acknowledge was the last transmission from the SATCOM.

The SATCOM link was available for most of the flight, excluding a period of between 22 and 78 minutes leading up to 1825 UTC, 07 March and a period of less than 8 minutes leading up to 0019 UTC, 08 March 2014. The absence of any aircraft-initiated handshakes, and on-going success of ground-initiated handshakes, indicates that power to the SATCOM was maintained other than the two periods stated above.

Data from the last seven 'handshakes' were used to help establish the most probable location of the aircraft. Initially only the first six of these 'handshakes' were considered to be complete. The seventh and last 'handshake' that was automatically initiated by the aircraft, was originally assessed as a partial 'handshake'. Subsequent analysis confirmed the 7th handshake could be used to help determine the most probable flight path. Two unanswered ground-to-air telephone calls had the effect of resetting the activity log and hence increased the period between the ground initiated 'handshakes'. The significant times used to identify the most probable final location of the aircraft are tabulated in *Table 1.9B* below. Details of the event's SATCOM ground station logs are provided in *Section 1.9.5 para. 3) and 4)* (below).

SATCOM TRANSMISSIONS		TIME	
		UTC	MYT*
1.	Aircraft departed KLIA	1642	0042
2.	Last ACARS transmission	1707	0107
3.	1st handshake - log-on initiated by the aircraft	1825	0225
4.	Unanswered ground-to-air telephone call	1839	0239
5.	2nd handshake initiated by ground station	1941	0341
6.	3rd handshake initiated by ground station	2041	0441
7.	4th handshake initiated by ground station	2141	0541
8.	5th handshake initiated by ground station	2241	0641
9.	Unanswered ground-to-air telephone call	2313	0713
10.	6th handshake initiated by ground station	0011*	0811
11.	7th handshake - log-on initiated by the aircraft	0019*	0819
12.	Aircraft did not respond to 'handshake' from Satellite Earth Ground Station	0115*	0915
* 08 March 2014			

Table 1.9B - SATCOM 'Handshakes'

3) Satellite Communications Ground Station Logs of the Event - Summary

The SATCOM utilised the Inmarsat Indian Ocean Region (IOR) I-3 satellite and the associated Perth Ground Earth Station (GES) throughout the flight. Inmarsat has confirmed that during the flight, no SATCOM signalling or traffic was routed via any other satellites (including MTSAT) to any other GESs (including MTSAT[11] GESs).

The SATCOM provides the Satellite link for the following functions:

- Cockpit Voice - Call control via the Multi-function Control and Display Units (MCDUs) and audio via the cockpit Audio Management Unit (AMU) and associated headsets;
- Cockpit Packet Data (Data-2) - Interface via the ACARS Management Unit (MU); and

[11] MTSAT - A series of Japanese weather and aviation satellites and GESs. MTSAT-1R and MTSAT-2 satellites are interoperable with Inmarsat satellites.

- Cabin Packet Data (Data-3) - Interface via the Panasonic System 3000i IFE equipment:
  - SMS/e-Mail
  - BITE-offload

The GES logs contain the following key information for each transmission to and from the aircraft:

- Time tag, Satellite and GES (Note: the timestamp accuracy does vary between the different logs, but should always be <1 second, and usually to a few milliseconds);

- Channel Type, Channel Number (frequency), Received Carrier/Noise Density Ratio (C/No), channel Bit-Error-Rate (BER), Burst Frequency Offset (BFO) and Burst Timing Offset (BTO, or round trip delay); and

- All payload data (excluding voice frames) contained within the transmission - these are known as the Signal Unit contents.

The events are summarised below. All times are in UTC. In the summary below, times are truncated to the nearest minute (the format is Hours Minutes) and in *Section 1.9.5 para. 4)*, times are truncated to the nearest second (the format is Hours Minutes:Seconds).

No.	Summary of SATCOM Ground Station Logs
1.	Prior to take-off, the SATCOM Logged On (normally) a number of times, the last time being at 1600, when it sent a valid Flight ID to the GES. The SATCOM link was available for both voice and data (known as Log-On Class 3).
2.	After take-off, the IFE SMS email application sent a normal beginning-of-flight message at 1642 (containing the correct Airborne Earth Station [AES ID], Flight ID "MAS370", origin airport "WMKK", and destination airport "ZBAA"), indicating that the IFE was receiving the valid Flight ID, origin airport and destination airport from AIMS and the ICAO (AES) ID from the Satellite Data Unit (SDU) at this time.
3.	The SATCOM link was available for most of the flight, excluding periods leading up to 1825 UTC, 07 March and 0019 UTC, 08 March 2014.

cont…

No.	Summary of SATCOM Ground Station Logs
4.	When the SATCOM link was re-established at the above times, no Flight ID was present
5.	During each of the two in-flight Log Ons at 1825 UTC and 0019 UTC, the GES recorded abnormal frequency offsets for the burst transmission from the SATCOM.
6.	There is no indication of the SATCOM link being manually Logged Off from the cockpit (via an MCDU). Such activity would have been captured in the GES logs, but it was not.
7.	No Data - 2 ACARS traffic was observed after 1707 UTC 07 March 2014.
8.	The IFE equipment set up two ground connections over SATCOM [for the SMS e-mail application and Built-In Test Equipment (BITE) application] after the SATCOM re-established the link at 1825 UTC, 07 March 2014 (normal), but not after the SATCOM re-established the link at 0019 UTC, 08 March (abnormal). At no time during the flight was any user data sent over the link by means of the SMS/e-Mail application.
9.	Two Ground-to-Air Telephone Calls were placed to the cockpit from MAS Operations Centre (MOC) at Airline Operational Communications (AOC) Q10 priority level at 1839 UTC and at 2313 UTC, 07 March 2014. Neither of the calls was answered.
10.	The SATCOM responded normally to a series of roughly hourly Log-On Interrogations from the Perth GES, up to and including a Log-On Interrogation at 0011 UTC, 08 March 2014. The two unanswered ground to air calls at 1839 UTC and 2313 UTC reset the Perth GES inactivity timer and hence the Log-On Interrogations were not always hourly.
11.	The last transmission received from the SATCOM occurred at 0019 UTC, 08 March 2014 and the SATCOM failed to respond to a series of three Log-On interrogations starting at 0115 UTC, 08 March 2014.

4) Satellite Communications Ground Station Logs – Key Observations (in chronological order) *(Table 1.9C* [below]*)*

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
1.	1250:19	Prior to take-off, the SATCOM initiates a normal Log-On as Class 1 (data only capable) via the Pacific Ocean Region (POR) I-3 satellite, using the Low Gain Antenna (LGA) subsystem, suggesting that ADIRU (Air Data Inertial Reference Unit) navigation data was not available to the SDU at this time. No flight ID is sent to the GES at this time. This is the first SATCOM activity recorded at the GES since 0802:27, suggesting that the SATCOM was not powered for a period of several hours, whilst the aircraft was on ground. This is quite normal.
2.	1555:57	The SATCOM initiates a normal Log On Renewal as Class 1 (data only capable) via the POR I-3 satellite, using the LGA subsystem, this time with a valid Flight ID.
3.	1557:49	The SATCOM initiates a normal Log-On as Class 3 (voice and data capable) via the POR I-3 satellite, using the High Gain Antenna (HGA) subsystem, with a valid Flight ID. This suggests that the ADIRU derived navigation data has become available at this time.
4.	1559:57	The SATCOM initiates a Log-On handover as Class 3 (voice and data capable) to the IOR I-3 satellite, using the HGA subsystem, with a valid Flight ID. This suggests that the IOR is now considered to be the best available satellite. This is probably because either the line of sight to the IOR satellite is now clearer than that to the POR satellite, or the antenna gain in the direction of the IOR satellite has become higher than the antenna gain in the direction of the POR satellite.
5.	1642:04	After take-off, the IFE SMS e-mail application sends a normal beginning-of-flight message. a. The message contained the correct AES ID, Flight ID "MAS370", origin airport "WMKK", and destination airport "ZBAA". b. This indicates that the IFE was receiving the Flight ID, origin airport and destination airport from AIMS and the ICAO (AES) ID from the SDU at this time.

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
6.	1707:48	Last DATA-2 ACARS Message received at the GES. No further SATCOM Data-2 ACARS messages or acknowledgements were received at the GES for the remainder of the flight. This is abnormal and suggests that the on-board ACARS equipment either failed, or was disabled or powered down at some time between 1707:48 and around 1825:00.
7.	1803:41	GES initiates a DATA-2 ACARS transmission (uplink), but receives no acknowledgement from the SATCOM. a. Therefore, the SATCOM Link was lost at sometime between 1707:48 and 1803:41. b. There is no evidence of a cockpit-initiated manual Log-Off of the SATCOM. c. Note that even if the on-board ACARs equipment was failed, disabled or powered down at this time, it would not prevent the SATCOM from acknowledging the ACARS-related P-Channel transmissions from the GES.
8.	1805:11	GES initiates a DATA-2 ACARS transmission, but receives no acknowledgement from the SATCOM, indicating that there is still no SATCOM link at this time.
9.	1825:27	SATCOM Log-On, initiated from the aircraft terminal. a. This is the first ‘handshake’. b. This marks the end of the link lost period that began at sometime between 1707:48 and 1803:41. c. This log-on request suggests that whatever caused the SATCOM link loss to occur between 1707:48 and 1803:41 had been reversed.
10.	1825:34	SATCOM Log-On, successfully completed. a. The SATCOM link becomes available (for both voice and data - Class 3) once more and normal SATCOM operation resumes (except that there is no Data-2 ACARS traffic). b. No Flight ID was sent to the GES during the Log-On. This implies that the SDU stopped receiving a valid Flight ID from the AIMS at sometime between 1642:04 and 1825:00. *cont…*

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
10. *cont…*	1825:34	c. The possible reasons for the link loss and the subsequent Log-On that took place at 1825:00 have been investigated and are detailed in *Table 2.5A*. There are many quite complicated scenarios that could have caused the 1825:00 Log-On. However, the most likely reason is a power interrupt to the SATCOM avionics, of a duration greater than 22 minutes (the time between events 7 and 9) and less than 78 minutes (the time between events 6 and 9). d. The GES recorded an abnormal BFO for the SATCOM Log-On Acknowledge transmissions (*Sections 1.9.5 para.* 5) and *2.5.3*). • 1825:00 Log-On Acknowledge - Most likely due to the power-on drift of the Oven Controlled Crystal Oscillator (OCXO), thus endorsing the belief that the 1825:00 Log-On was preceded by a lengthy power interrupt. An OCXO provides a stable reference frequency for the SDU Radio Frequency (RF) transmit and receive circuits and also for SDU modem timing. Within the OCXO, a regulated oven keeps the crystal at an almost constant temperature if the ambient temperature in the crown area is between the ranges -55^{o}C up to above +70^{o}C. The oven also contains extra electrical regulation and isolation to ensure frequency accuracy and stability. The OCXO includes an oven ready flag, which triggers the Log-On initiation when the OCXO reaches its operating temperature. Extensive laboratory testing has revealed that during warm up, the OCXO frequency may vary non-linearly with time, but then settles with almost negligible variation. At power-on, the OCXO can exhibit either a rising or falling frequency gradient, before decaying over time to its normal steady state value. The testing has indicated that reasonable stability (within 2Hz/minute) is typically reached by around five minutes after an initial peak or overshoot. The testing has also shown that there can still be a significant frequency offset at the time that the oven ready flag initiates the Log-On process, so the Log-On request, Log-On Acknowledge and subsequent data bursts can all exhibit significant frequency offsets.

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
11.	1827:03	The IFE sets up a Data-3 ground connection (X.25 circuit) over SATCOM for an SMS/e-mail application after the SATCOM link is re-established.
12.	1828:05	The IFE sets up a Data-3 ground connection (X.25 circuit) over SATCOM for a BITE application after the SATCOM link is re-established.
13.	1839:52	Ground-to-air telephony call placed from a number with country code 60 (Malaysia) a. Q10 Airline Operational Communications (AOC) Priority Level b. The Perth GES logs indicate that a good link is likely to have existed at this time. c. This call would have been routed to the cockpit and should have resulted in a chime and an incoming visual annunciation on the Audio Control Panels (ACPs), and, if the appropriate SATCOM page was selected, then also on one or more MCDU. d. The GES logs show zero duration, indicating that the call went unanswered. Note that there are two methods for the answering of an incoming call: Either by pressing the relevant Line Select Key on an MCDU, or by keying a microphone.
14.	1840:56	The GES logs show that the unanswered Ground-to-Air telephony call was cleared by the calling party.
15.	1941:00	Log-On Interrogation by the Perth GES, with a response from the SATCOM a. This is the second ‘handshake’, whereby the GES inactivity timer has expired and the GES has sent a message to interrogate the status of the SATCOM. b. The SATCOM responded normally and the SATCOM link was therefore available at this time.
16.	2041:02	Log-On Interrogation by the Perth GES, with a response from the SATCOM a. This is the third ‘handshake’. b. The SATCOM responded normally and the SATCOM link was therefore available at this time.

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
17.	2141:24	Log-On Interrogation by the Perth GES, with a response from the SATCOM a. This is the fourth 'handshake'. b. The SATCOM responded normally and the SATCOM link was therefore available at this time.
18.	2241:19	Log-On Interrogation by the Perth GES, with a response from the SATCOM a. This is the fifth 'handshake'. b. The SATCOM responded normally and the SATCOM link was therefore available at this time.
19.	2313:58	Ground-to-air telephony call placed from a number with country code 60 (Malaysia) a. Q10 AOC Priority Level. b. The Perth GES logs indicate that a good link is likely to have existed at this time. c. This call would have been routed to the cockpit and should have resulted in a chime and an incoming visual annunciation on the Audio Control Panels, and, if the appropriate SATCOM page was selected, then also on one or more MCDU. d. The GES logs show zero duration, indicating that the call went unanswered. Note that there are two methods for the answering of an incoming call: Either by pressing the relevant Line Select Key on an MCDU, or by keying a microphone.
20.	2315:02	The GES logs show that the unanswered Ground to Air telephony call was cleared by the calling party.
21.	0010:58	Log-On Interrogation by the Perth GES, with a response from the SATCOM a. This is the sixth 'handshake'. b. The SATCOM responded normally and the SATCOM link was therefore available at this time.

Table 1.9C - Chronology of Satellite Communications Ground Station Log

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
22.	0019:29	SATCOM Log-On, initiated from the aircraft terminal. This is the seventh 'handshake'. a. For there to have been a Log-On at this time, there must have been a prior loss of the SATCOM link. This link loss must have occurred at some time after 0010:58, when the SATCOM responded to a Log-On interrogation. b. This Log-On request suggests that whatever caused the SATCOM link loss to occur had been reversed.
23.	0019:37	SATCOM Log-On, successfully completed a. The SATCOM link becomes available (for voice and data – Class 3) once more and normal SATCOM operation resumes. b. No Flight ID was sent to the GES during the Log-On. This infers that the SDU was still not receiving the Flight ID from AIMS. c. The possible reasons for the link loss and the subsequent Log-On that took place at 0019:00 have been investigated and are detailed in Section 2.5.2. There are many quite complicated scenarios that could have caused the 0019:00 Log-On with no Flight ID. However, the most likely reason is a power interrupt to the SATCOM avionics, of a duration less than 8 minutes. d. The GES recorded an abnormal frequency offset for the SATCOM Log-On Request and Acknowledge transmissions (see *Sections 1.9.5 para. 5) and 2.5.3*). The abnormal BFOs for the 0019 Log-On Request and Log-On Acknowledge are more likely due to a combination of uncompensated vertical velocity (descent) and OCXO warm up drift. e) The IFE did not subsequently establish the two Data-3 X.25 connections over the SATCOM, which it normally does if it is functional. It can be inferred that the IFE was either not operating at this time (powered off, not being powered whilst the SATCOM was being powered by the APU, failed, or still resetting after a power cycle), or the SATCOM and/or the IFE became inoperative before the IFE was able to establish the Data-3 connection <u>Note:</u> This is the last transmission received from the aircraft terminal.

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

cont…

No.	Time (UTC)	Key Observations - Satellite Ground Station Logs
24.	0115:56	Log-On Interrogation by the Perth GES, with no response from the SATCOM a. The SATCOM Link was lost at sometime between 0019:37 and 0115:56. b. There is no evidence of a cockpit-initiated manual Log-Off of the SATCOM. c. The loss of SATCOM link was due to one of the following: i. The SATCOM stopped receiving the P-Channel transmission from the satellite ii. SATCOM input power (115VAC 400Hz) was removed iii. The SATCOM experienced a BITE failure.
25.	0116:06	Log-On Interrogation by the Perth GES, with no response from the SATCOM.
26.	0116:15	Log-On Interrogation by the Perth GES, with no response from the SATCOM.

Table 1.9C - Chronology of Satellite Communications Ground Station Logs

5) Frequencies of Log-On Bursts

During each of the two in-flight Log-Ons that occurred at 1825 and 0019, the GES recorded abnormal frequency offsets for the SATCOM transmissions. This is in contrast with the ‘normal’ Log-On behaviour.

Table 1.9D (below) shows the frequencies of these Log-On bursts, as measured at the GES, plus differences from assumed reference frequencies (closest stable values in time, where the aircraft is assumed to be in level flight). The table also shows the very high delta frequencies between the respective Log-On Request and Log-On Acknowledge bursts.

Log-On Time	1825	0019
BFO used as a reference (closest stable value, assume level flight)	144Hz @ 1828:05	252Hz @ 0010:59
Log-On Request BFO	142Hz @ 1825:27	182Hz @ 0019:29
Log-On Request C/No recorded at GES	30.28	40.59
Log-On Request Channel BER recorded at GES	5	0
Log-On Request Difference Frequency (from BFO reference)	-2Hz @ 1825:27	-70Hz @ 0019:29
Log-On Acknowledge BFO	273Hz @ 1825:34	-2Hz @ 0019:37
Log-On Acknowledge C/No recorded at GES	42.55	43.38
Log-On Acknowledge Channel BER recorded at GES	0	0
Log-On Acknowledge Difference Frequency (from BFO reference)	+129Hz @ 1825:34	-254Hz @ 0019:37
Delta frequency between the Log-On Request and the Log-On Acknowledge bursts, plus time period	+131Hz over 7 seconds	-184Hz over 8 seconds

Table 1.9D - Log-On Bursts

SECTION 1 – FACTUAL INFORMATION

1.10 AERODROME INFORMATION

Not applicable.

SECTION 1 – FACTUAL INFORMATION

1.11 FLIGHT RECORDERS

The aircraft was equipped with two crash-protected recorders:

- Solid State Flight Data Recorder (SSFDR)
- Solid State Cockpit Voice Recorder (SSCVR)

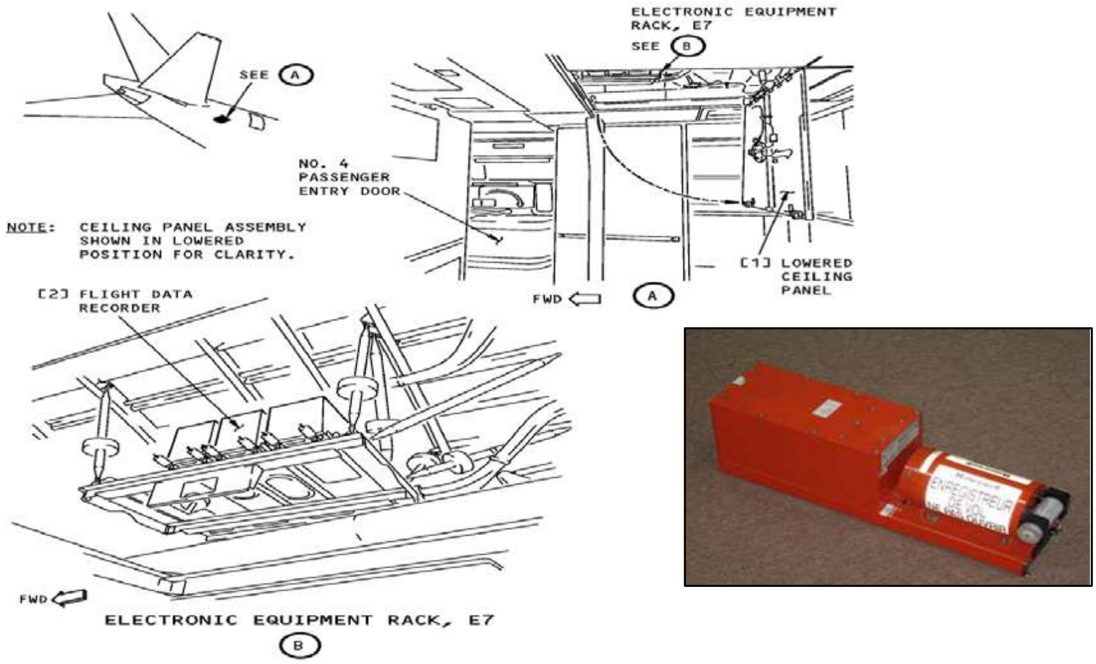

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Figure 1.11A - Location of Solid State Flight Data Recorder

1.11.1 Solid State Flight Data Recorder

The solid state flight data recorder (SSFDR) is located in the Electronic Equipment rack, E7, which is in the aft cabin above the ceiling (*Figure. 1.11A* [above]).

The SSFDR receives and stores selected aircraft parameters from various aircraft systems and sensors in a crash-protected solid state memory.

The flight data recorder system (FDRS) operates during any engine start, while any engine is running, during test or when the aircraft is in the air. The SSFDR is powered from the right AC transfer bus which is powered by the engine generators or the APU generator. If none of these generators are functioning due to non-operation of the engines and APU then the bus will not be powered and the SSFDR will not operate in the air.

This is a solid state flight data recorder (SSFDR) with a recording capacity of at least twenty-five hours.

The SSFDR records the most recent 25 hours of flight and records more than 1300 parameters. The SSFDR is a 256 word per second (wps) data rate recorder. The most recent flight data recorder download for this aircraft was in September 2013 and this was carried out for the annual readout. The annual readout extracts 151 parameters for evaluation. Details of the SSFDR installed and specifications are as follows:

- Manufacturer: Honeywell
- Model: SSFDR Model 4700
- Part Number (P/N): 980-4700-042
- Serial Number (S/N): SSFDR-08636
- Date last installed on aircraft: 26 August 2012
- Weight: 6.8 kg
- Electricity Consumption: 15 W, 115 VAC 400 Hz
- Impact Shock: 3400 G for 6.5 ms
- Fire Temperature: Max 1100°C (30 min)
- Deep Sea Pressure and Sea Water Immersion: 20,000 ft.

1.11.2 Solid State Cockpit Voice Recorder

The solid state cockpit voice recorder (SSCVR) is in the Electronic Equipment Rack, E7, in the aft cabin above the ceiling and located adjacent to the SSFDR (*Figure 1-11B* [below]).

The SSCVR has a recording capacity of at least two hours in standard quality and thirty minutes in high quality.

The voice recorder system receives cockpit sounds and flight crew communications. It keeps this audio in a solid state memory.

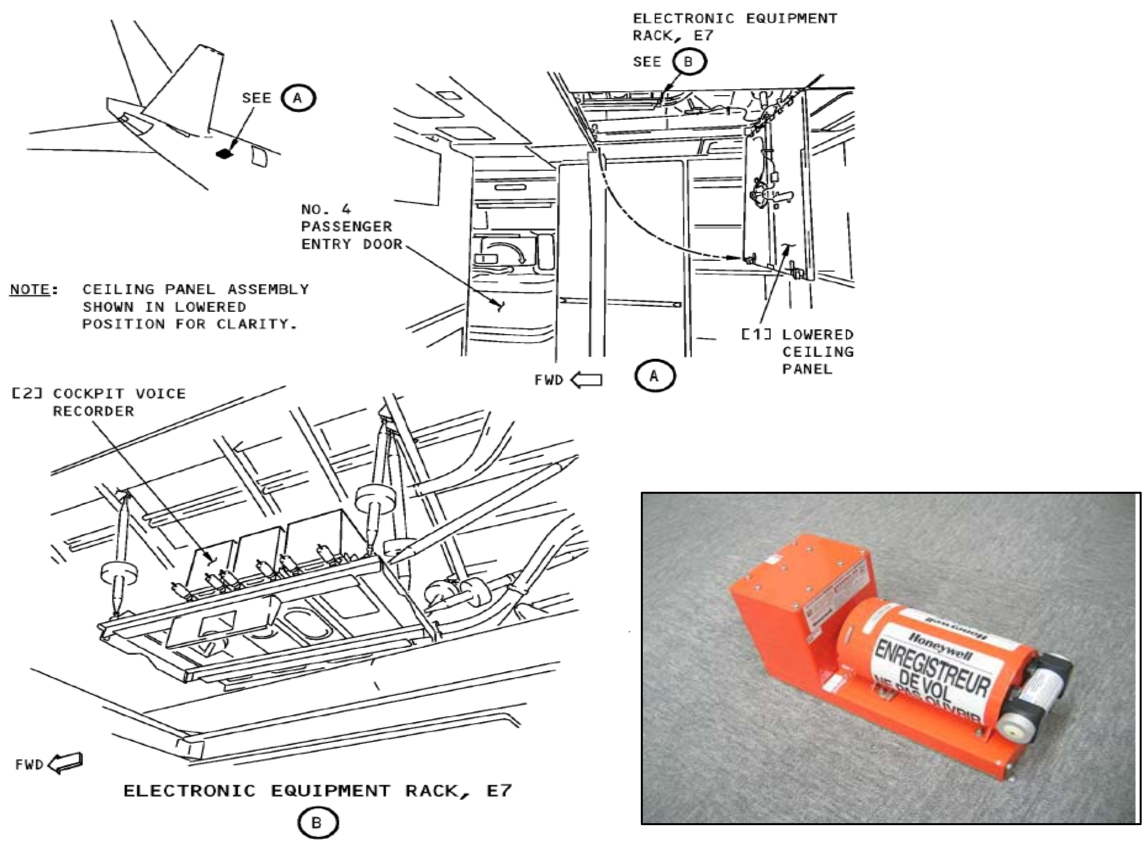

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Figure 1.11B - Location of Solid State Cockpit Voice Recorder

Four audio channels go to the SSCVR. Channel 1, 2, and 3 audio is from the audio management unit (AMU). Each channel carries audio from one crew member's flight interphone audio. The audio on each channel is the sum of these signals:

- Hot mic audio (microphone audio when there is no press-to-talk [PTT])
- Received audio as selected on the crew member's audio control panel (ACP)
- Side tone audio to the crew member

Channel 4 audio is from the Cockpit Area Microphone (CAM). The CAM sends cockpit area audio to the SSCVR. The SSCVR operates any time power is available on the Left AC transfer bus. This bus is not powered from batteries or the Ram Air Turbine (RAT).

Details of the SSCVR installed and the specifications are as follows:

- Manufacturer: Honeywell
- Model: SSCVR Model 6022
- Part Number (P/N): 980-6022-001
- Serial Number (S/N): 2677
- Date last installed on aircraft: 26 August 2012
- Weight: 5.9 kg Electricity Consumption: 8 W, 115 VAC 400 Hz
- Impact Shock: 3400 G for 6.5 ms
- Fire Temperature: Max 1100°C (30 min)
- Deep Sea Pressure and Sea Water Immersion: 20,000 ft.

1.11.3 Underwater Locator Beacons

Both crash-protected recorders were equipped as provided by the regulations with underwater locator beacons (ULB) whose transmission time is at least 30 days, on the 37.5 kHz frequency, operating depth up to 20,000 ft (6096 m) and activated with fresh or salt water immersion. Detail specifications are as per below:

- Manufacturer: Dukane
- Model: DK-100 / DK-120
- Operating Frequency: 37.5 kHz ± 1 kHz
- Operating Depth: Surface to 20,000 ft. (6,096 meters)
- Pulse Length: 10 milliseconds + 10%
- Pulse Repetition Rate: Not less than 0.9 Pulse/Sec
- Operating Life: 30 days (minimum)
- Battery Life In Beacon: 6 Years
- Acoustic Output, Initial: 1060 dynes/cm^2 rms pressure at 1 meter (160.5 dB)
- Acoustic Output After 30 Days: 700 dynes/cm^2 rms pressure at 1 meter (157.0 dB)
- Operating Temperature Range: +28°F (-2.2°C) to +100°F (+37.8°C)
- Actuation: Fresh or salt water
- Radiation Pattern: Rated output over 80 percent of sphere
- Size: 1.30 inches (3.30 cm) diameter x 3.92 inches (9.95 cm) long (less mount)
- Weight, Beacon: 6.7 ounces (190 grams)
- Storage Temperature Range: -65°F (-54°C) to 160°F (71°C)

The SSFDR was attached with a ULB as below:

- S/N: SC26210
- ULB Expiry Date: December 2012

The SSCVR was attached with ULB as below:

- S/N: Not Recorded
- ULB Expiry Date: June 2014

1) Solid State Flight Data Recorder Underwater Locator Beacon Battery Expiry

According to maintenance records, the solid state flight data recorder (SSFDR) Underwater Locator Beacon's (ULB) battery expired in December 2012. There is no evidence to suggest that the SSFDR ULB battery had been replaced before the expiry date. The SSCVR ULB battery however was replaced, as scheduled, with the next expiry in June 2014.

Technical Log records showed that the SSFDR (together with the ULB) was replaced on the aircraft on 29 February 2008. Component installation records for the ULB showed that at the time the SSFDR was replaced on aircraft the expiry date for the battery was December 2012.

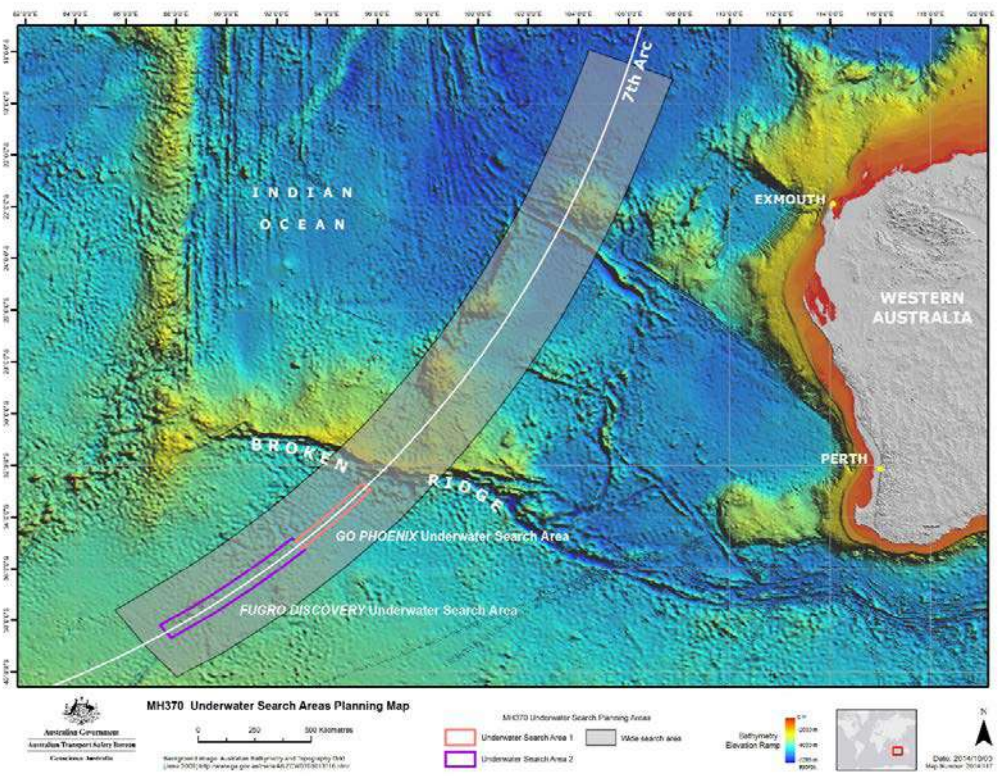
SECTION 1 – FACTUAL INFORMATION

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 Introduction

Extensive work by the the MH370 Search Strategy Group, coordinated by the ATSB, by analysing signals transmitted by the aircraft's satellite communications terminal to Inmarsat's Indian Ocean Region satellite indicated that the aircraft ended its flight in the Southern Indian Ocean.

The ATSB led the underwater search for MH370 in the southern Indian Ocean. The search area, as shown (below) in *Figure 1.12A*, covered in excess of 120,000 sq. km at the 7th Arc.



Source: ATSB

Figure 1.12A - MH370 Search Area

Further search was carried out by the US company, Ocean Infinity, which covered an area of more than 112,000 sq. km towards the north of the area covered by ATSB on the 7th arc.

No wreckage of the aircraft has been found after the completion of the search. However, several floating components and debris confirmed/possibly from MH370 have been found as far as the south eastern coast of Africa. Refer to *Figure 1.12B* (below).

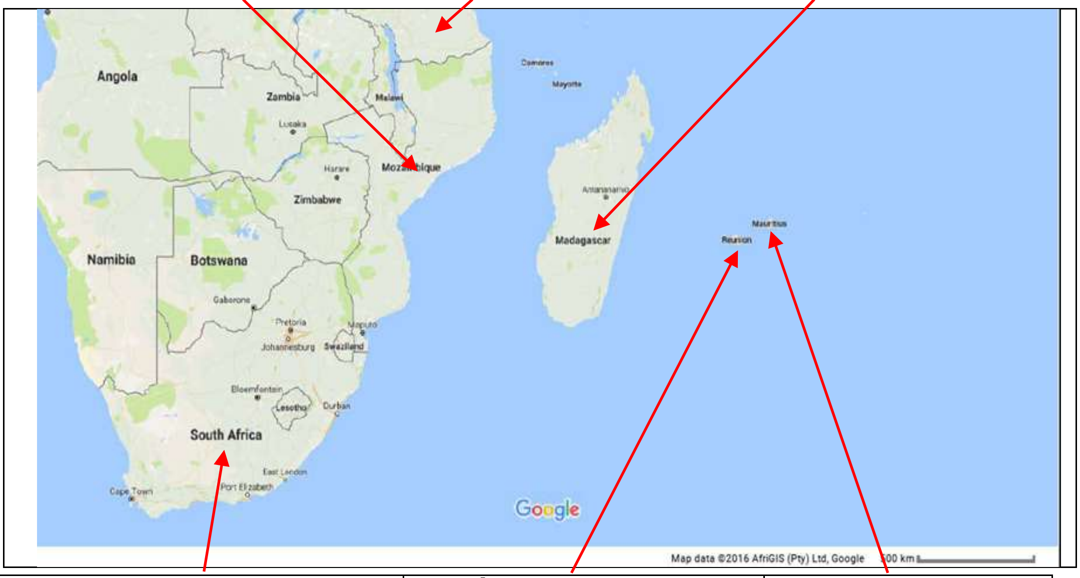
1.12.2 Location of Where the Debris were Found

After a number of assessments, more than 20 items were considered for further examination. These items were found in the north west corner of the Indian Ocean, namely in Réunion Island, Mozambique, Tanzania,

MOZAMBIQUE					
Item					
2	3	6	7	9	22

TANZANIA
Item
19

MADAGASCAR					
Item					
11	12	13	14	15	16
17	18	23	24	25	-



SOUTH AFRICA				
Item				
4	20	21	26	27

RÉUNION ISLAND
Item
1

MAURITIUS		
Item		
5	8	10

Keys		Item	Status	Total
	(teal)	1, 10 & 19	*Confirmed*	3
	(blue)	2,3,4,5,6,16 & 22	*Almost Certain*	7
	(orange)	8, 9, 11, 15, 18, 20 26 & 27	*Highly Likely*	8
	(yellow)	7 & 12	*Likely*	2
	(grey)	13, 14, 17, 21, 23, 24 & 25	*Not Identifiable*	7
	Total			27

Figure 1.12B - Locations and Status of Identification of the Debris

South Africa, Madagascar and Mauritius. *Figure 1.12B* (above) shows the distribution of the debris found in the above respective areas. *Table 1.12A* (below) provides a summary of the items of debris examined.

<table>
<tr><th>Ref.</th><th>Date Found</th><th>Debris</th><th>Location</th><th>Remarks</th></tr>
<tr><td>Item 1</td><td>29 July 2015</td><td>
Right Flaperon</td><td>

Saint-Denis, Réunion Island</td><td>

- *Confirmed* by French Judicial Authority belonging to MH370 on 03 September 2015
- Refer to *Appendix 1.12A-1* and *Appendix 1.12A-2*

</td></tr>
<tr><td>Item 2</td><td>27 December 2015</td><td>

Right Wing No. 7 Flap Support Fairing</td><td>

Daghatane Beach, Mozambique</td><td>

- Examination showed that part is *almost certain* from MH370
- Refer to *Appendix 1.12B*

</td></tr>
</table>

Table 1.12A - Items of Debris

cont…

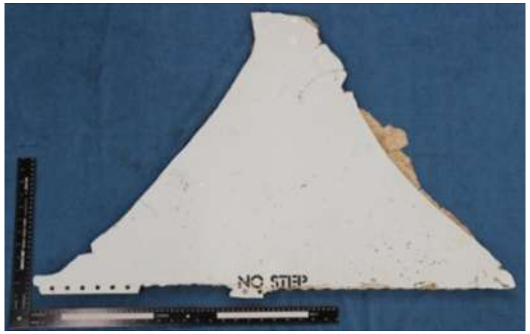
Ref.	Date Found	Debris	Location	Remarks
Item 3	27 February 2016	 Right Horizontal Stabiliser Panel	 Valankulo, Paluma Sandbank, Mozambique	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12B*
Item 4	22 March 2016	 Engine Nose Cowl	 Mossel Bay, South Africa	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12C*

Table 1.12A - Items of Debris

cont...

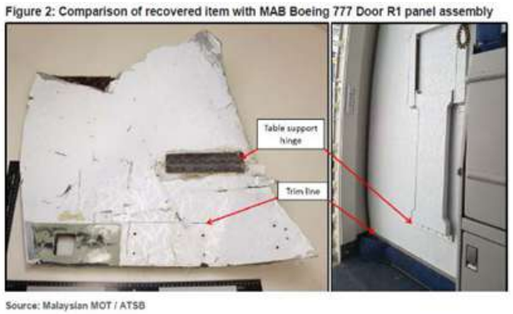
Ref.	Date Found	Debris	Location	Remarks
Item 5	30 March 2016	 Door R1 Stowage Closet	 Rodrigues, Mauritius	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12C*
Item 6	24 April 2016	 Right Hand Engine Fan Cowling	 South of Chidenguele, Mozambique	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12D*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 7	30 April 2016	 Wing to Body Fairing	 Anvil Bay, Chemucane, Mozambique	• Examination showed that part is *likely* from MH370 • Refer to *Appendix 1.12E*
Item 8	24 May 2016	 No. 1 Flap Support Fairing Tail Cone	 Gris Gris Beach, Mauritius	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12F*

Table 1.12A - Items of Debris

cont...

Ref.	Date Found	Debris	Location	Remarks
Item 9	22 May 2016	 Left Wing Trailing Edge Panel	 Macenta Peninsular, Mozambique	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12G*
Item 10	10 May 2016	 Left Outboard Flap	 Ilot Bernache, Mauritius	• This part is *confirmed* from MH370 • Refer to *Appendix 1.12H*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 11	06 June 2016	 Seat Back Trim Panel encasing IFE Monitor	 Riake beach, Nosy Boraha Island, Madagascar	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12I*
Item 12	06 June 2016	 Bottom panel on the Wing or Horizontal Stabilizer	 Riake beach, Nosy Boraha Island, Madagascar	• Examination showed that part is *likely* from MH370 • Refer to *Appendix 1.12J*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 13	12 June 2016	 Unidentified part	 Riake beach, Nosy Boraha Island, Madagascar	• Not identifiable • Refer to *Appendix 1.12K*
Item 14	12 June 2016	 Unidentified part	 Riake beach, Nosy Boraha Island, Madagascar	• Not identifiable • Refer to *Appendix 1.12L*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 15	06 June 2016	 Right Wing Trailing Edge Panel	 Riake beach, Nosy Boraha Island, Madagascar	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12G*
Item 16	12 June 2016	 Cabin Interior Panel	 Antsiraka beach, Madagascar	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12M*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 17	12 June 2016	 Unidentified part	 Antsiraka beach, Madagascar	• Not identifiable • Refer to *Appendix 1.12M*
Item 18	12 June 2016	 Right Forward Nose Landing Gear Door	 Antsiraka beach, Madagascar	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12N*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 19	20 June 2016	 Right Outboard Flap	 Pemba Island, East of Tanzania	• The part is *confirmed* from MH370 • Refer to *Appendix 1.12O*
Item 20	21 June 2016	 Right Aft Wing to Body Fairing	 Kosi Bay Mouth, Kwa Zulu Natal, South Africa	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12P*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 21	18 July 2016	 Unidentified Part	 Northern Kwa Zulu Natal, South Africa	• Not identifiable • Refer to *Appendix 1.12Q*
Item 22	26 August 2016	 Right Vertical Stabilizer Panel	 Linga Linga beach Mozambique	• Examination showed that part is *almost certain* from MH370 • Refer to *Appendix 1.12R*

Table 1.12A - Items of Debris

cont…

<table>
<tr><th>Ref.</th><th>Date Found</th><th>Debris</th><th>Location</th><th>Remarks</th></tr>
<tr><td>Item 23</td><td>October 2016</td><td>
Unidentified Part</td><td>

Riake beach, Nosy Boraha Island, Madagascar</td><td>• Not identifiable
• Refer to Appendix 1.12S</td></tr>
<tr><td>Item 24</td><td>February 2016</td><td>
Unidentified Part</td><td>

Saint Luce, Madagascar</td><td>• Not Identifiable
• Refer to Appendix 1.12T</td></tr>
</table>

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 25	July 2016	 Unidentified Part	 Riake beach, Nosy Boraha Island, Madagascar	• Not identifiable • Refer to *Appendix 1.12U*
Item 26	23 December 2016	 Right Aileron	 Nautilus Bay, South Africa	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12V*

Table 1.12A - Items of Debris

cont…

Ref.	Date Found	Debris	Location	Remarks
Item 27	27 January 2017	 Right Wing No. 7 Flap Support Fairing	 Mpame Beach, South Africa	• Examination showed that part is *highly likely* from MH370 • Refer to *Appendix 1.12W*

Table 1.12A - Items of Debris

1.12.3 Details of the Debris

The debris are briefly described in the following paragraphs. The details of the parts will be found in the *Appendix 1.12A* to *Appendix 1.12W* of this report.

1) Item 1 - Right Flaperon

Item No. 1 was found on 29 July 2015 in Saint-Denis, Réunion Island. Réunion Island is a French territory in the Indian Ocean.

This item was one of the biggest and complete part of an aircraft found washed ashore. The item was retrieved by the local French authorities and shipped to General Delegate of Armament Aeronautical Technique (DGA/TA) facility in Toulouse for detailed examination. Because of a court case pending in Paris, the part was taken custody by the French Investigative Judge, as evidence for a criminal investigation.

The part identification, detailed examination and analysis were carried out at DGA/TA in Toulouse under the directive and jurisdiction of the French Investigative judge. Although the name plate was missing, which could have provided immediate traceability to the aircraft (9M-MRO), the part was *confirmed* to be a right flaperon of the aircraft 9M-MRO, by tracing the identification numbers of the internal parts of the flaperon to their manufacturing records at EADS CASA, Spain. Refer to *Appendix 1.12A-1.*

The examination of the flaperon at DGA/TA revealed the following damages:

a) the inboard and outboard hinge fittings were fractured in two places; at the level of the leading edge and on the lower surface of the flaperon;

b) the fracture surfaces on the hinge fittings were highly corroded;

c) the ribs at the edge of the flaperon showed, in their metallic area, holes due to corrosion;

d) the leading edge showed dents and cracks;

e) the trailing edge was generally broken;

f) the lower and upper surface panels showed localised dents and the upper surface had a large crack; and

g) the mounting attachment zones on each side of the flaperon were damaged or broken off.

In addition, the flaperon was covered with a colony of barnacles. Most of them were on the upper surface (extrados).

Refer to *Appendix 1.12A-2* for details.

2) Item 2 - Right Wing No. 7 Flap Support Fairing

Item No. 2 was found on 27 December 2015 in Daghatane Beach, Mozambique.

The item was brought to ATSB Laboratory in Canberra for detailed examination and analysis. The part was identified from a number stencilled on the part (676EB), as a segment from a Boeing 777 flap track (support) fairing (Fairing No. 7) from the right wing. All measurable dimensions, materials, construction and other identifiable features conformed to the applicable Boeing drawings for the identified fairing. It was concluded that the item is *almost certain* from MAS B777 aircraft, registered 9M-MRO.

Refer to *Appendix 1.12B* for details.

3) Item 3 - Right Horizontal Stabilizer Panel Piece

Item No. 3 was found on 27 February 2016 in Valankulo, Paluma Sandbank, Mozambique.

The item was brought to ATSB Laboratory in Canberra for detailed examination and analysis. The part was primarily identified from images showing the materials, construction and “NO STEP” stencil, as a segment of a Boeing 777 right horizontal stabilizer panel. All measurable dimensions, materials, construction and other identifiable features conformed to the Boeing drawings for the stabiliser panel. It was concluded that the item is *almost certain* from MAS B777 aircraft, registered 9M-MRO.

Refer to *Appendix 1.12B* for details.

4) Item 4 - Engine Nose Cowl

Item No. 4 was found on 22 March 2016 in Mossel Bay, South Africa.

The item was brought to ATSB Laboratory in Canberra for detailed examination and analysis. The part was identified from the partial Rolls-Royce stencil as a segment from an aircraft engine cowling. The panel thickness, materials and construction conformed to the applicable drawings for Boeing 777 engine cowlings. There were no identifiers on the engine cowling segment that were unique to 9M-MRO, however the Rolls-Royce stencil font and detail did not match the original from manufacture. The stencil was consistent with that developed and used by MAS and closely matched exemplar stencils on other MAS B777 aircraft. There were no significant differentiators on the cowling segment to assist in determining whether the item of debris was from the left or right side of the aircraft, or the inboard or outboard side of the cowling. It was concluded that the item is *almost certain* from MAS B777 aircraft, registered 9M-MRO.

Refer to *Appendix 1.12C* for details.

5) Item 5 - Door R1 Stowage Closet

Item No. 5 was found on 30 March 2016 in Rodrigues Island of Mauritius.

The item was brought to ATSB Laboratory in Canberra for detailed examination and analysis. The part was identified by the decorative laminate as an interior panel from the main cabin. The location of a piano hinge on the part surface was consistent with a work-table support leg, utilised on the exterior of the MAS Door R1 (forward, right hand) closet panel. The part materials, dimensions, construction and fasteners were all consistent with the drawing for the panel assembly and matched that installed on other MAS Boeing 777 aircraft at the Door R1 location.

There were no identifiers on the panel segment that were unique to 9M-MRO, however the pattern, colour and texture of the laminate was only specified by MAS for use on Boeing 747 and 777 aircraft. There is no record of the laminate being used by any other Boeing 777 customers.

It was concluded that the item is *almost certain* from MAS B777 aircraft, registered 9M-MRO.

Refer to *Appendix 1.12C* for details.

6) Item 6 - Right Hand Engine Fan Cowling

Item No. 6 was found on 24 April 2016, south of Chidenguele, Mozambique. The item was brought back to Malaysia for identification and further examination by the Team. The possible location of the debris on a MAS B777 aircraft was determined. The hinge bracket, number of fasteners and fasteners' pitch on the part were consistent with those on the right engine fan cowl on the aircraft. The mount found on the part was also consistent with the mount of the fan cowl "Hold-Open Stay Rod" in regards to its location, shape and size of the mounting bracket. The words "HOIST POINT" were still visible and in the correct location. The fonts used for the words on the part matched those on the fan cowl of the aircraft. The part was brought near to the right fan cowl and was found to physically resemble it in terms of shape, size, colour and features.

It has been concluded that the debris is part of the Right Fan Cowl of a B777. As the right fan cowls on both the engines are similar, there is no conclusive evidence to determine whether it belongs to the left (No. 1) or right (No. 2) engine. Based on the other features on the recovered part it has also been determined that the part is *almost certain* from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12D* for details.

7) Item 7 - Unidentified Part

Item No. 7 was found on 30 April 2016 on Anvil Bay, Chemucane, Mozambique. The item was brought back to Malaysia for identification and further examination by the Team.

The exact location of the debris on a MAS B777 aircraft could not be identified since it did not have any markings or numbers and there were no peculiar features which could match it on the aircraft except for one edge of the part which had a distinct radius, which suggested that the joining part would be at an angle.

While the construction was similar to a B777 part, there was no conclusive evidence to determine the origin of this part with respect to the aircraft. After review of the B777 Illustrated Parts Catalogue (IPC), the most possible location of the part was determined to be the wing to fuselage body fairing.

There is no conclusive evidence to determine the origin of this part with respect to the aircraft however it is likely to be a part of a panel of the wing to body fairing on a B777 and it is *likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12E* for details.

8) Item 8 - Flap Support Fairing Tail Cone

Item No. 8 was found on 24 May 2016 on Gris Gris Beach, Mauritius. The item was brought back to Malaysia for identification and further examination by the Team.

Initial assessment indicated that this could be a flap support fairing tail cone of a B777. The part was identified from the legible numbers that were observed on the inner surface. The following part number 113W9154-401 and serial number 407 were visible on one side. The profile of the part resembled the wing flap support fairing tail cone.

The part number was cross referenced to the Boeing component maintenance manual and drawings. This identified it as a component of the wing flap fairing assembly and the fit closely matched that of the No. 1 flap support fairing. As the records of where these fairing tail cones are fitted are not normally kept by airlines, the serial number 407 could not be tracked to any particular aircraft.

Based on the legible numbers and the fit, it is confirmed that it is the tail cone of the No. 1 flap support fairing of B777 and *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12F* for details.

9) Item 9 - Left Wing Trailing Edge Panel

The item was found on 22 May 2016 in Macenta Peninsular, Mozambique. The item was brought back to Malaysia for identification and further examination by the Team.

The item matched the left part (outboard section) of the Upper Fixed Panel forward of the flaperon on the left wing. It was observed that the outboard side was fractured and on the inboard side the fastener holes were still visible with a pitch of 1 in. This fastener pitch matched that on the inboard side of the panel of the aircraft. The fasteners' pitch on the outboard side is 2 in. The raised portion of the core of the section of the panel of length 18 in. also matched with that on the aircraft panel.

The item is confirmed to be the outboard section of the "Upper Fixed Panel forward of the flaperon" on the left wing. The debris is *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12G* for details.

10) Item 10 - Left Outboard Flap

Item No. 10 was found on 08 May 2016 at Ilot Bernache, Mauritius. A part number was identified on a section of the debris, identifying it as a trailing edge splice strap, incorporated into the rear spar assembly of a Boeing 777 left outboard flap. This was consistent with the appearance and construction of the debris.

Adjacent to the part number was a second part identifier. The flap manufacturer supplied records indicating that this identifier was a unique work order number and that the referred part was incorporated into the outboard flap shipset line number 404 which corresponded to the Boeing 777 aircraft line number 404, registered 9M-MRO and operating as MH370.

Refer to *Appendix 1.12H* for details.

11) Item 11 - Seat Back Trim Panel Encasing IFE Monitor

Item No. 11 was found on 06 June 2016 on Riake beach, Nosy Boraha Island, Madagascar.

The item was brought back to Malaysia for the identification and further examination by the Team.

The part was identified as the seat back trim panel which encases the In-Flight Entertainment (IFE) monitor. There was a small fragment of fabric around the coat hanger on the debris, which was greenish in colour. This colour matched the seat fabric used on the MAS B777 on the centre seats. The location of the coat hanger on the left conforms to the Right Hand, Triple Seat Assembly column in the Economy (EY) class.

This part is confirmed to be the seat back trim panel for encasing the IFE monitor and is *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12I* for details.

12) Item 12 - Bottom Panel on Wing or Horizontal Stabilizer

Item No. 12 was found on 06 June 2016 on Riake beach, Nosy Boraha Island, Madagascar.

The item was brought back to Malaysia for identification and further examination by the Team. The letters "FB" were clearly visible on the part which indicates that it is a bottom panel on the wing or horizontal stabilizer. An attempt was made to match the part to all the wing and horizontal stabilizer panels with the identification marks ending with "FB". The thickness and profile of the part did not match any of those panels on the aircraft. However, it could be confirmed that it is very likely to be a part from a Boeing aircraft and *likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12J* for details.

13) Item 13 - Unidentified Part

Item No. 13 was found on 06 June 2016 on Riake beach, Nosy Boraha Island, Madagascar.

The item was brought back to Malaysia for the further examination and identification by the Team. The part could not be matched exactly to any part on a MAS B777 aircraft. There were also no identification numbers on the part.

Refer to *Appendix 1.12K* for details.

14) Item 14 - Unidentified Part

Item No. 14 was found on 06 June 2016 in Riake beach, Nosy Boraha Island, Madagascar.

The item was brought back to Malaysia for identification and further examination by the Team. The part did not have any distinguishing features to match any on a MAS B777 aircraft. It did not have any identification numbers. The part resembled a cabin interior piece based on the decorative finish, however there was insufficient evidence to positively identify the part to be from an aircraft.

Refer to *Appendix 1.12L* for details.

15) Item 15 - Right Wing Trailing Edge Panel

Item No. 15 was found on 06 June 2016 in Riake beach, Nosy Boraha Island, Madagascar.

The item was brought back to Malaysia for identification and further examination by the Team.

It was identified to be the outboard section of the “Upper Fixed Panel forward of the flaperon” on the right wing of a MAS B777 aircraft. The pitch of the fasteners’ holes on the right side (outboard) of the panel was measured to be 2 in. and that matched that on the debris. The debris is *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12G* for details.

16)Item 16 - Cabin Interior Panel

Item No. 16 was found on 12 June 2016 on Antsiraka beach, Madagascar.

The piece was small and did not have any evidence of part number printed on it. The vinyl cover showed a unique pattern of interior decorative panel on one side and white vinyl on the other side of the piece. The pattern was similar to the one used on MAS 777 cabin interior panels. There were also ‘insert’ holes visible on one of the sides. The part has been determined to be *almost certain* from MH370.

The detailed examination was conducted by the Team in collaboration with Science & Technology Research Institute for Defence (STRIDE).

Refer to *Appendix 1.12M* for details.

17)Item 17 - Unidentified Part

Item No. 17 was found on 12 June 2016 on Antsiraka beach, Madagascar.

This item is a sandwich structure panel with Nomex Honeycomb core of typical aircraft composite structure. No markings were found on this item. Further analysis on this item is difficult due to lack of features to indicate that it could be a B777 part.

Refer to *Appendix 1.12M* for details.

18)Item 18 - Right Forward Nose Landing Gear Door

Item No. 18 was found on 12 June 2016 in Antsiraka beach, Madagascar.

The item was brought back to Malaysia for the identification and further examination by the Team.

The part did not have any identification numbers on it. However, the features on the part resembled the Right Nose Gear Forward Door of a MAS B777 aircraft. The oval depressions on the inner skin and the orientation of a diagonal, raised bar matched that on the Right Nose Gear Forward Door on the aircraft.

The part is positively identified as the Right Hand Nose Gear Forward Door of a B777. It is *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12N* for details.

19)Item 19 - Right Outboard Flap

Item No. 19 was found on 21 June 2016 in Pemba Island, East of Tanzania. This is the largest piece found after the flaperon and has been determined to be part of the inboard section of the right outboard flap of a B777. The Italian part manufacturer build records for the numbers located on the part *confirm* that all of the numbers relate to the same serial number outboard flap that was shipped to Boeing as line number 404. Aircraft line number 404 was delivered to MAS and registered as 9M-MRO.

Refer to *Appendix 1.12O* for details

A fibreglass and aluminium seal pan located at the inboard end of this outboard flap was found damaged. Two adjacent aluminium stiffeners within this inboard seal pan area also exhibited damage which was due to impact.

Refer to *Appendix 2.5C* for details.

20)Item 20 - Right Aft Wing to Body Fairing

Item No. 20 was found on 21 June 2016 on Kosi Bay Mouth, Kwa Zulu Natal, South Africa.

The item was brought back to Malaysia for identification and further examination by the Team. Part of the identification number was visible on the debris indicating that it is part of the right aft wing to body fairing panel, 196 MR. Part of the part number, 149W5232-1, was visible with the letter 'R' below it, indicating it is a panel on the right side of the aircraft.

This item is confirmed to be part of the right aft wing to body fairing panel from a B777 aircraft. It is *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12P* for details.

21)Item 21 - Unidentified Part

Item No. 21 was found on 18 July 2016 in Northern Kwa Zulu Natal, South Africa.

The item was brought back to Malaysia for identification and further examination by the Team. Based on the structure construction, this part could be a small section of a panel from an aircraft. There were no identification numbers on the part and it could not be positively determined from which aircraft and which section it could have come from. It could not be positively determined whether the debris could be from a B777 aircraft.

Refer to *Appendix 1.12Q* for details.

22)Item 22 - Vertical Stabilizer Panel

Item No. 22 was found on 26 August 2016 on Linga Linga beach Mozambique.

The item was brought back to Malaysia for the identification and further examination by the Team.

On the interior side of the part, there was still a decal with part identification numbers. The Assembly (Assy) Number 177W3103-8 was visible. When referred to the Boeing 777 Illustrated Parts Catalog (IPC) this part was confirmed to be the right vertical stabilizer panel between the auxiliary and front spar. The red/white paint on the panel and the paint configuration appeared to match that of the MAS ‘kite’ logo on the right side of the vertical stabilizer.

The debris is confirmed to be part of the right vertical stabilizer panel of a B777. Based on the red/white livery on the panel it is determined to be *almost certain* from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12R* for details.

23) Item 23 - Unidentified Part

This item was recovered from Riake Beach, Nosy Bohara Island, Madagascar in October 2016.

The item was brought back to Malaysia for the identification and further examination by the Team.

The part structure construction characteristics showed that it was not part of the aircraft structure. It appeared more likely to be from the aircraft interior based on the vinyl and edge sealant which was on the part. The vinyl and sealant colour on the part matched that of the parts generally used in aircraft galleys. Although it appeared to be part of an aircraft interior there is no conclusive evidence to indicate whether the part could have actually originated from an aircraft.

Refer to *Appendix 1.12S* for details.

24) Item 24 - Unidentified Part

Two items of fibreglass-honeycomb composite debris were recovered near Sainte Luce on the south-east coast of Madagascar, having reportedly washed ashore in February 2016.

They were hand-delivered to the ATSB on 12 September 2016. The items were initially reported in the media as being burnt.

No manufacturing identifiers, such as a part numbers or serial numbers were present on either item that may have provided direct clues as to their origin. Despite no evidence of overall gross heat damage, two small (<10mm) marks on one side of the larger item and one on the reverse side were identified as damage resulting from localised heating. A burnt odour emanating from the large item was isolated to these discrete areas. The origin and age of these marks was not apparent. However, it was considered that burning odours would generally dissipate after an extended period of environmental exposure, including salt water immersion, as expected for items originating from 9M-MRO.

Refer to *Appendix 1.12T* for details.

25) Item 25 - Unidentified Part

This item was recovered from Riake beach, Nosy Boraha Island, Madagascar in July 2016.

The item was brought back to Malaysia for examination and identification by the Team. There were no identification numbers on the part and with the available features it could not be matched to any part on a MAS B777 aircraft.

Refer to *Appendix 1.12U* for details.

26) Item 26 - Right Aileron

This item was recovered from Nautilus bay, South Africa on 23 December 2016.

The item was brought back to Malaysia for identification and further examination by the Team. The debris closely matched the inboard section of the Right Aileron on a MAS B777 aircraft.

The numbers on the head of the fasteners on the debris were compared with those on the inboard section of the right aileron on the aircraft. These numbers matched. Additionally, the spacing of the fasteners on the aileron also matched those on the debris. The core and its dimensions also matched those on the inboard section of the right aileron. These confirmed that the debris is part of the inboard section of the right aileron of a B777 aircraft.

Based on the dimensions and fit on the aircraft and the visible fasteners it could be confirmed that the debris is part of the inboard section of the right aileron of a B777 aircraft. It was also determined to be *highly likely* from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12V* for details.

27) Item 27 - Right Wing No. 7 Flap Support Fairing

This item was recovered from Mpame beach, South Africa on 27 January 2017.

The item was brought back to Malaysia for identification and further examination by the Team. The possible location of the part on a MAS B777 aircraft was determined.

It was easily matched to the fixed, forward portion of the No. 7 flap support fairing. Item No. 2, found on 27 December 2015 at Daghatane Beach, Mozambique, is also part of the same fairing; however, it is part of the rear, moveable section.

The debris was thoroughly cleaned to reveal any identification numbers. After cleaning, the numbers 113W9211-402, S/N: 406 were found on the inside surface of the debris. The part number 113W9211-402 indicated that the debris was indeed a part of the No. 7 flap support fairing of a B777 aircraft. The serial number, 406 could not be used to link it to any particular aircraft as there were no records available to confirm this.

Based on the legible part number and the match of the part on the aircraft it is confirmed that the debris is part of the fixed, forward No. 7 flap support fairing of a B777 aircraft, and also determined to be *highly likely* to be from MH370 (aircraft registered as 9M-MRO).

Refer to *Appendix 1.12W* for details.

1.12.4 Process for Recovery of Debris

At the time of writing of this report, the possibility exists that more debris might be found washed ashore, especially at the coasts of south east Africa. Arrangements have been made with the Civil Aviation Authorities there to retrieve and secure the debris and to be delivered to the Team for examination.

SECTION 1 – FACTUAL INFORMATION

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Medical information relating to the crew is under *Section 1.5.*

Loss of aircraft cabin pressure, or depressurisation, is a potentially serious emergency in an aircraft flying at normal cruising altitude. Depressurisation, also known as decompression, is the reduction of atmospheric pressure inside a contained space such as the cabin of a pressurised aircraft. The cabins of modern passenger aircraft are pressurised in order to create an environment which is physiologically suitable for humans. The higher the aircraft flies, the higher the pressure differential that needs to be maintained and the higher the stress on the aircraft structure. Without a fully functional pressurised cabin, passengers and crew need to use oxygen systems during cruise. The composition of atmospheric air remains constant as air pressure reduces with increasing altitude. Since the partial pressure of oxygen also reduces, the absolute amount of oxygen also reduces. The reduction in air pressure reduces the flow of oxygen across lung tissue and into the human bloodstream. A significant reduction in the normal concentration of oxygen in the bloodstream is called hypoxia.

Hypoxia is a condition in which the body or a region of the body is deprived of adequate oxygen supply at the tissue level. The major symptoms and signs of hypoxia include light headedness or dizziness, blurred or tunnel vision, headache or nausea, diminished hearing and tingling or numbness of finger tips. The effects of hypoxia become more significant when exposed to an altitude above 10,000 ft.

Time of useful consciousness or also known as effective performance time is the amount of time crew and passengers can continue to conduct duties and activities in an environment with inadequate oxygen. It is measured from the time when the occupants of the aircraft are exposed to a low-pressure environment to the time when the occupants have lost the capability to take corrective and protective actions, such as self-administration of oxygen. The time of useful consciousness is dependent on the pressure altitude inside the cabin following depressurisation (Refer to *Table 1.13A* below). Hypoxia symptoms can be worse and time of useful consciousness shorter for people with respiratory or heart conditions, who are smokers and unfit, or have been drinking alcohol.

There was no evidence that physiological factors or incapacitation affected the performance of flight crew members on MH370.

Cabin Pressure Altitude (ft)	*Time of Useful Consciousness (TUC)*
15,000	More than 30 min
18,000	20 – 30 min
22,000	10 min
25,000	3 – 5 min
28,000	2.5 – 3 min
30,000	1 – 2 min
35,000	30 sec – 1 min
40,000	15 – 20 sec
Source: Reinhart, R.O. 1996. Basic Flight Pathology. 2nd Edition. McGraw-Hill: New York.	

Table 1.13A: Time of Useful Consciousness

SECTION 1 – FACTUAL INFORMATION

1.14 FIRE

Aircraft fire could not be established as there was no reported air or ground fire.

SECTION 1 – FACTUAL INFORMATION

1.15 SURVIVABILITY

Survivability of persons on board could not be established as the aircraft has not been found.

SECTION 1 – FACTUAL INFORMATION

1.16 TESTS AND RESEARCH

Not applicable.

SECTION 1 – FACTUAL INFORMATION

1.17 ORGANISATIONAL AND MANAGEMENT INFORMATION

1.17.1 Department of Civil Aviation Malaysia

1) Introduction

The Department of Civil Aviation **(**DCA) is an agency under the purview of the Ministry of Transport (MOT) with the authority to regulate and oversee all technical-operational aspects of the civil aviation industry in Malaysia.

As a Contracting State of the International Civil Aviation Organization (ICAO) since 1958 Malaysia through DCA is responsible to ensure that the safety and security of flights are consistently maintained at the highest level possible, and at the same time, to ensure the safety of the Malaysian airspace for aircraft operations in conformity to the requirements of ICAO in all aspect of polices, regulations and Standards and Recommended Practices (SARPs).

Malaysia's civil aviation system is based on the Federal Constitution as the supreme law. The legal framework in place consists of the following legislations enacted by Parliament:

- Civil Aviation Act 1969 (Act 3), last amended 01 June 2003
- Aviation Offences Act 1984 (Act 307);
- Airport and Aviation Services (Operating Company) Act 1991 (Act 467); and
- Carriage by Air Act 1974 (Act 148).

Specifically, Section 3 of the *Civil Aviation Act 1969* empowers the Minister of Transport *"to give effect to the Chicago Convention and regulate civil aviation.''* Under the authority conferred by the same provision, the Minister of Transport also enacted the *Civil Aviation Regulations 1996 (CAR) [P.U. (A) 139/96].*

CAR 201 stipulates the use of '*ipso facto*' to address ICAO Annexes 1 to 19, including the application of not only ICAO Standards, but also the recommended practices, provided that a regulation has not already been established in CAR and that a difference has not been notified to ICAO. In particular, DCA relies completely on CAR 201 for the implementation of Annexes 3, 4, 5 and 12.

The *Civil Aviation Act 1969* or Act 3 also empowers the Minister of Transport to make rules providing for *"the investigation in such manner as may be prescribed, including by means of a tribunal established for the purpose, of any accident either occurring in Malaysia or occurring to Malaysian aircraft."* In addition, this Act provides the Minister of Transport, the Chief Inspector of Air Accidents Investigation Bureau (AAIB) with the proper authority and legal tools to conduct investigations effectively, and in compliance with Annex 13.

CAR defines which accidents and incidents shall be reported and empowers the Minister of Transport to appoint a Chief Inspector of Air Accidents and Incidents. CAR provides for the Chief Inspector to *"determine whether or not an investigation shall be carried out in respect of any accident to which these regulations apply and the form of the investigation"*. The Chief Inspector may carry out, or may cause another Inspector to carry out, an investigation of any such accident. CAR also makes provision for the mandatory submission of a report to the Director-General of Civil Aviation (DGCA) in respect of any reportable occurrence. No provision is however made for a voluntary non-punitive reporting system.

2) Functions and Responsibilities of Department of Civil Aviation

The functions and responsibilities of DCA are, as follows:

- To exercise regulatory functions in respect of civil aviation and airport and aviation services including the establishment of standards and their enforcement;
- To represent the Government in respect of civil aviation matters and to do all things necessary for this purpose;
- To ensure the safe and orderly growth of civil aviation throughout Malaysia;
- To encourage the development of airways, airport and air navigation facilities for civil aviation;

- To promote the provision of efficient airport and aviation services by the licensed Company; and

- To promote the interests of users of airport and aviation services in Malaysia in respect of the prices charged for, and the quality and variety of, services provided by the licensed Company.

3) Sectors and Divisions of Department of Civil Aviation

<table>
<tr><th colspan="2">Sectors and Divisions of DCA</th></tr>
<tr><td>1. Flight Operations Sector</td><td rowspan="3">Grouped under a broader unit called Engineering and Flight Operations</td></tr>
<tr><td>2. Airworthiness Sector</td></tr>
<tr><td>3. Flight Calibration Division</td></tr>
<tr><td colspan="2">4. Air Traffic Management Sector</td></tr>
<tr><td colspan="2">5. Air Traffic Management Inspectorate Division</td></tr>
<tr><td colspan="2">6. Aviation Security Division</td></tr>
<tr><td colspan="2">7. Airport Standards Division</td></tr>
<tr><td colspan="2">8. Malaysian Aviation Academy Division</td></tr>
</table>

4) Areas of Focus

Section 1.17.1 will focus on three Sectors of DCA, as below:

a) Air Traffic Management Sector,

b) Airworthiness Sector, and

c) Flight Operations Sector.

5) Air Traffic Management Sector

The Director of the Air Traffic Management (ATM) Sector is responsible to the DGCA for the planning, implementation and operation of the air traffic services systems in the two Malaysian Flight Information Regions (FIRs), i.e. Kuala Lumpur and Kota Kinabalu FIRs respectively, in accordance with the ICAO Standards and Recommended Practices (SARPs).

The function of the ATM Sector is responsible for the provision of air traffic service for the safe and efficient conduct of flight within Malaysian airspace pursuant to the Chicago Convention 1944.

The Malaysian airspace is divided into the Kuala Lumpur and Kota Kinabalu FIRs, where operations are associated with air traffic control units. There are two Air Traffic Control Centres; in Kuala Lumpur and Kota Kinabalu, a sub-centre in Kuching as well as 12 Control Towers in Peninsular Malaysia, 4 in Sabah and 8 in Sarawak.

The Director of ATM Sector is supported by Regional Director I (Peninsular Malaysia), Regional Director II (Sabah), Regional Director III (Sarawak), Director KLIA and Director of KL ATSC in the functionality of the Sector.

Supporting the Regional Directors/Directors are ATSC Chiefs, Supervisors, DCA Managers, Unit Chiefs, Operational Controllers and support staff. Other entities, including Aeronautical Information Service (AIS), Procedures for Air Navigation Services and Operations (PANS-OPS), Cartography and SAR are under the direct responsibility of the Director of ATM Sector. The ICAO SARPs associated with the responsibility of ATM Sector are those contained in:

- Annex 1 - Personnel licensing;
- Annex 2 - Rules of the Air;
- Annex 3 - Meteorological Service for International Air Navigation;
- Annex 4 - Aeronautical Charts;
- Annex 5 - Units of Measurement to be used in Air and Ground Operations
- Annex 10 - Aeronautical Telecommunications Volume I & II;
- Annex 11 - Air Traffic Services;
- Annex 12 - Search and Rescue;
- Annex 14 - Aerodromes; and
- Annex 15 - Aeronautical Information Services.

Other relevant documents are:

- DOC 4444 - Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM);
- DOC 9859 - Safety Management System Manual;
- CIR 314 - Threat and Error Management (TEM);
- DOC 9910 - Normal Operations Survey (NOSS);
- DOC 9426 - Air Traffic Services Planning Manual; and
- DOC 9683 - Human Factors Training Manual.

a) Air Traffic Inspectorate Division

The Air Traffic Inspectorate (ATI) Division is the regulatory body that oversees the provision of Air Navigation Services (ANS) by the ANS providers to ensure compliance with the national legislations, namely the Civil Aviation Act 1969 and the Civil Aviation Regulations 1996, and ANS-related ICAO Annexes to the Chicago Convention.

The ATI Division develops and establishes the ANS safety standards and performs safety oversight and surveillance activities with the sole aim of regulating the ANS providers. The regulatory Manual of ANS Inspectorate contains the requirements and procedures pertaining to the provision of the ANS, based on the SARPs of ICAO Annexes to the Chicago Convention, other ICAO documents and best practices, as may be determined by the ATI Division which develops and establishes the ANS safety standards and performs safety oversight to be applicable in Malaysia. From time to time the ATI Division develops and establishes the ANS safety standards and performs safety oversight and may supplement these ANS safety standards in the form of safety publications such as Air Traffic Inspectorate Directives (ATIDS) or Aeronautical Information Circulars (AIC). Where appropriate, these safety publications will be incorporated into the Manual by amendments.

i) Audits/Inspections

The audits/inspections utilise protocols questions and compliance checklists to evaluate the level of adherence to stipulated national legislations, and ANS-related ICAO Annexes to the Chicago Convention and ICAO documents, including best practices. The ATI Division also conducts oversight of the ANS provider's safety management system (SMS) to ensure its formal and systematic implementation by all ATSUs, including compliance with stipulated requirements. Currently, the ANS providers that are regulated by the ATI Division include Air Traffic Management Sector of DCA, Malaysian Meteorology Department, Royal Malaysian Air Force (RMAF) and the Malaysian Army.

ii) Personnel Licensing

Personnel Licensing for ATCOs provisions was promulgated in the Malaysia Civil Aviation Regulations (MCAR) 1996. The ATI Division is the authority for issuance, renewal, endorsement and validation of an ATC Licence and an ATC Trainee Licence (implemented since 01 April 2011), in accordance with ICAO Annex 1 to the Chicago Convention.

(1) Air Traffic Control Examination activities include all ATC courses at ATC organisations that are approved by the DGCA and operational ATC examinations at ATS units that control civil air traffic. However, some functions are delegated to designated ATC Check Officers who are appointed on a two-year basis by the DGCA.

(2) Air Traffic Control Licensing provisions were promulgated in the MCAR 1996. The ATI Division is the authority for issuance, renewal, endorsement and validation of an ATC Licence and an ATC Trainee Licence in accordance with ICAO Annex 1 to the Chicago Convention, as follows:

(3) Class 3 Medical Assessment for ATCOs, as part of the pre-requisite for an ATC Licence and an ATC Trainee Licence,

shall only be issued by a Designated Aviation Medical Examiner (DAME). The ATI Division develops and establishes the ANS safety standards and performs safety oversight and maintains a comprehensive database of licensing information for all licensed holders, and

(4) English Language Proficiency (ELP) Assessment is required for ATCOs and aeronautical station operators, and they must meet the minimum required proficiency level for radiotelephony communications i.e. Level 4 in accordance with ICAO Annex 1 to the Chicago Convention.

iii) Certification and Audit of ATC Approved Training Organisation

The Certification and Audit of ATC Approved Training Organisation (ATC-ATO) is responsible for the training of ATCOs. It provides ATC training by holding ATC-ATO approval certificate that is issued by the DGCA. The ATI Division conducts a regular oversight programme on the approved ATC-ATO to ensure continuing compliance with the approval requirements.

iv) Air Traffic Control Incident Investigations

Air Traffic Control Incident Investigations are carried out for ATC safety-related occurrences to evaluate the effectiveness of the ATC system and its components, as well as recommending mitigation actions towards enhancements. The investigative process includes the Incident Review Panel (IRP), The Board of Inquiry (BOI) and the Safety Review Boards (SRB).

In addition to the licensing and validation of ATCOs, the ATI Division develops and establishes the ANS safety standards and performs safety oversight and is responsible for regulating the checks and standards units at various ATS facilities. It also conducts safety oversight of military ATCOs who are charged with the responsibility of providing air traffic services to civil flights in selected portions of the airspace.

The ATI Division develops and establishes the ANS safety standards and performs safety oversight and has also developed appropriate processes and procedures to enable the division to carry out its safety oversight functions in accordance with established requirements and in a standardised manner. The Division has the necessary facilities and equipment to enable the personnel to carry out their safety oversight functions in an effective manner. All necessary procedures, including guidance material, have been developed.

v) Search and Rescue

With respect to Search and Rescue (SAR), no legislation specifically addresses the provision of assistance to aircraft in distress. However, in Malaysia, aeronautical SAR (A-SAR) is provided in accordance with Annex 12 to the Convention of ICAO and International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual Vol. I to IV.

As a signatory to the Chicago Convention, Malaysia is obligated to provide A-SAR services on a 24-hour basis, within the Malaysian Aeronautical Search and Rescue Regions (SRR), (defined within the Kuala Lumpur and Kota Kinabalu FIRs).

With the implementation of National Security Council (NSC) Directive No. 20 effective 11 May 1977, A-SAR Operational procedures have been amended to harmonise with inter-agency actions during an aeronautical incident.

vi) Primary Aeronautical and Maritime Search and Rescue Agencies

(1) National Security Council

The National Security Council (NSC) is the body responsible for establishing, developing and maintaining Aeronautical and Maritime SAR Organisation in Malaysia. The Cabinet, through the Secretary of the National Security Council, directs the NSC on policy, international agreements, conventions and operational matter. The

NSC is responsible to the Cabinet on all matters pertaining to Aeronautical and Maritime SAR.

Note:

The National Security Council Act 2016 was enacted by the Parliament of Malaysia and published in the *Gazette* on 07 June 2016.

(2) Department of Civil Aviation

DCA is the SAR Authority for aeronautical incidents and shall be responsible for the provision of Aeronautical SAR service within Malaysia's Aeronautical Search and Rescue Regions (SRRs). As such DCA shall co-ordinate, liaise, train, equip, staff, maintain, develop procedures and operations and conduct exercises for A-SAR. DCA shall also assist the Maritime SAR Authority, when requested.

(3) Malaysian Maritime Enforcement Agency

The Malaysia Maritime Enforcement Agency (MMEA) is the SAR Authority for maritime incidents and shall be responsible for the provision of Maritime SAR service within Malaysia's Maritime SRRs. As such MMEA shall co-ordinate, liaise, train, equip, staff, maintain, develop procedures and operations and conduct exercises for maritime SAR. MMEA shall also assist the Aeronautical SAR Authority, when required.

vii) Aeronautical Search and Rescue Plan of Operation

The purpose of this plan is to provide a set of specific Aeronautical SAR Operation Procedures in all SAR missions within the Malaysian SRRs, for which DCA is the SAR Authority for aeronautical incidents and, acts as Chairman to the Aeronautical SAR Working Group. However, this plan is, by no means, exhaustive in nature, and is to be used in conjunction with IAMSAR MANUAL VOLUMES I, II, and III and as well as other departmental documents issued from time to time. Operational Letters of Agreements have also been signed with neighbouring States/SAR Regions. The preparedness and training of all entities is ensured through regular exercise and training.

viii) International Search and Rescue Treaties, Conventions and Agreements

DCA Malaysia had participated in a number of international organisations such as ICAO, and in accordance with the Convention on international Civil Aviation has adopted search and rescue (SAR) standards and practices. Additionally, there are SAR bilateral agreements between Malaysia and the ASEAN countries (Indonesia, Singapore, Thailand, Brunei and the Philippines) SAR agencies to enhance coordination, cooperation and mutual support for operations along commons borders.

(1) Search and Rescue Agreements:

(a) Multilateral

As a member state of the Association of South East Asia Nations (ASEAN), and in line with the Declaration of ASEAN Concord for Cooperation between the member states of Indonesia, Philippines, Singapore and Thailand, Malaysia has formalised the following on aeronautical and maritime SAR:

ASEAN Agreements for the facilitations of search for aircraft in distress and rescue of survivors of aircraft accidents, signed in Singapore on 14 April 1972; and

ASEAN Agreements for the facilitations of search for ships in distress and rescue of survivors of accidents, signed in Kuala Lumpur on May 1975.

(b) Bilateral

Malaysia has also signed Bilateral Aeronautical SAR Agreements with the following countries:

1.	Singapore	11 August 1984
2.	Thailand	09 August 1985
3.	Indonesia	29 August 1985
4.	Philippines	09 December 1985
5.	Brunei Darussalam	16 December 1998

(c) Other Arrangements

Special operational procedures for border SAR Malaysia/Indonesia by the General Border Committee, resulting from the special arrangements between the Malaysia/Indonesia SAR Working Group of both countries.

Under the Operational Letter of Agreements between Singapore and Malaysia pertaining to aeronautical SAR service in the South China Sea Corridor Area[12], Kuala Lumpur ACC shall take alerting actions while Singapore RCC shall conduct the aeronautical SAR mission (AIP Malaysia Volume I ENR 2.2-3).

It is noted that the SAR responsibilities over the high seas/Malaysia Exclusive Economic Zone (EEZ) within the KL FIR/ASRR over Malaysia Maritime SAR Region (MSRR) shall be under the jurisdiction of Malaysia SAR authorities.

[12] South China Sea Corridor Area is defined as the area West of 105E at flight level 150 to Ground/Sea Level and East of 105E at flight level 200 to Ground/Sea Level, within the dimensions of 023600N 1044500E to 020000N 107000E and along 020000N till the Singapore/Kota Kinabalu FIR boundary - thence along 060000N till the Singapore/ Kuala Lumpur FIR Boundary - thence along this boundary to 023600N1044500E)

(d) Area of Responsibility

In accordance with ICAO agreements, the international boundaries for the provision of the search and rescue (SAR) services in Malaysia and adjacent ocean areas are divided into two search and rescue regions (SRRs) for aeronautical coordination.

(e) Search and Rescue Regions of Malaysia

As promulgated in the ICAO's Regional Air Navigation Plan, the Search and Rescue Regions of Malaysia are defined as the areas coincide with the boundaries of the Kuala Lumpur and Kota Kinabalu Flight Information Regions; airspace as delegated by Aeronautical SAR Region (ASRR) Appendix ICAO under Malaysia's jurisdiction. The Malaysia ASRR area of responsibility is, as *Figure 1.17A* (below).

(f) Maritime Search and Rescue Regions

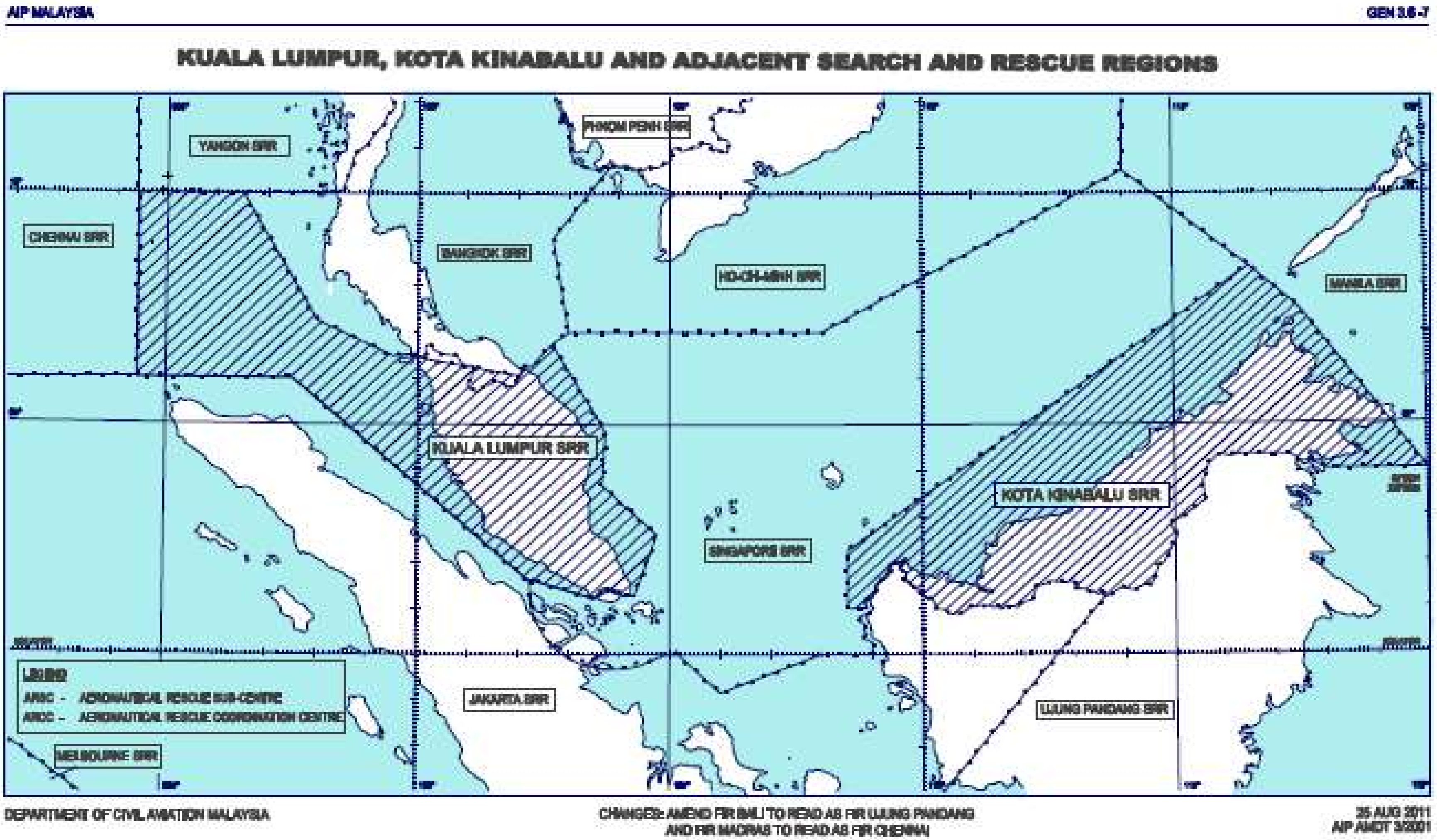
The Malaysia Maritime Search and Rescue Regions (MSSR) - *Figure 1.17B* (below), include the waters of Malaysia and the areas declared as the Continental Shelf Boundary and also the waters under the FIRs delegated to Malaysia. This information is published in IMO SAR Plan.

(g) Responsibilities of Department of Civil Aviation on Search and Rescue

The responsibilities of DCA on Search and Rescue are as follows:

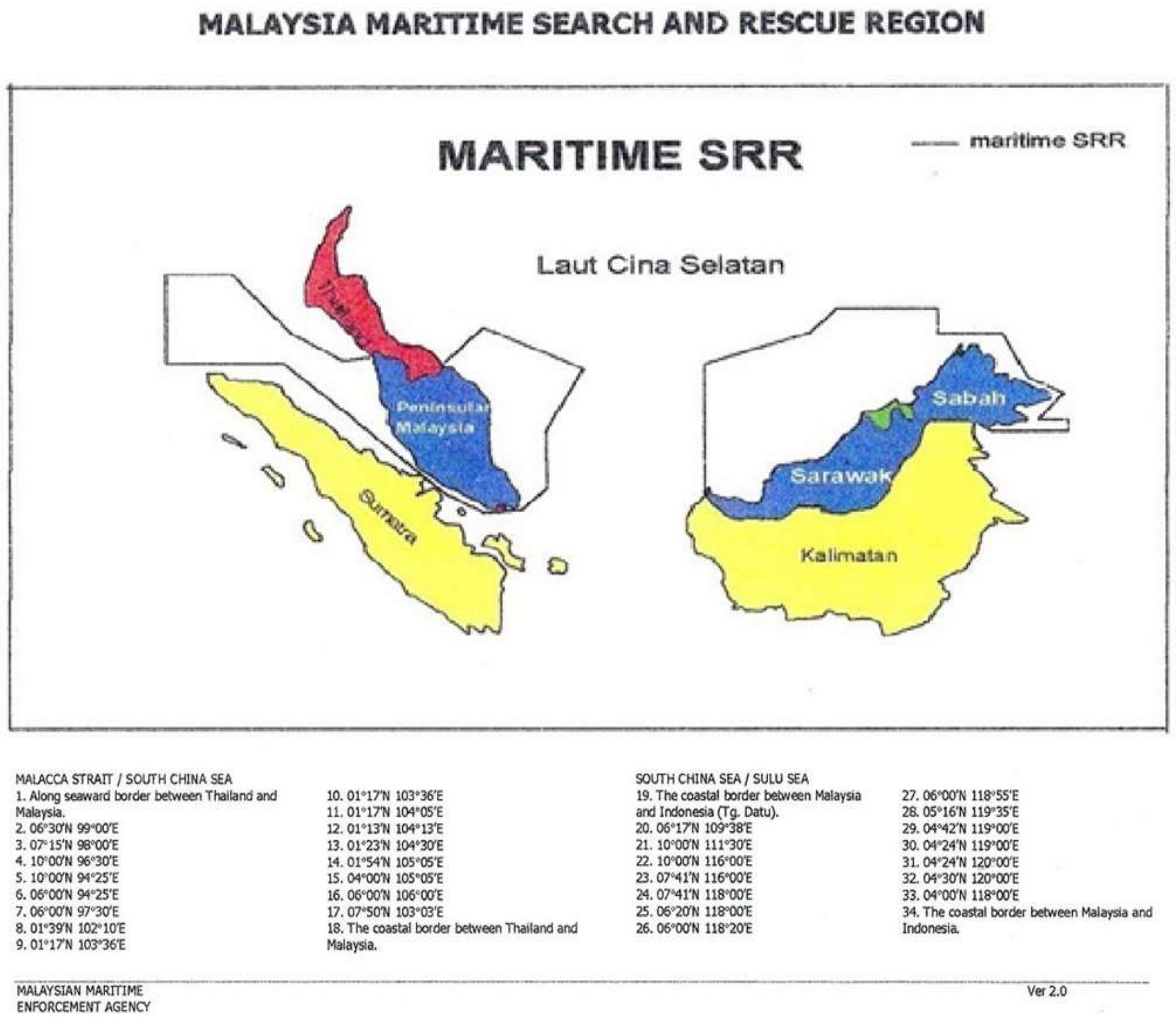
- Developing SAR policies;
- Developing A-SAR bilateral agreements with adjacent states;

- Establishing, staffing, equipment and managing the A-SAR system;
- Conduct training courses in search and rescue at the Civil Aviation Academy and refresher courses at the ARCC;
- Coordinate for SAR training and refresher courses;
- Establishing of ARCCs and ARSC;
- Arranging for SAR facilities; Conduct and coordinate all SAR missions involving civil aircraft within its areas of responsibility.
- Assist in the conduct of all SAR missions involving military aircraft, when requested by RMAF;
- Assist in the conduct of SAR missions involving vessel when requested by MRCC/MRSC;
- Provision and maintenance of the KL ARCC, KK ARCC and Kuching ARSC; and
- Tasking of SAR participating aircraft or vessel for search and rescue operations:
    - Provision of survival equipment; and
    - Periodically conduct national and international search and rescue exercises (SAREX).



Source: DCA Malaysia

Figure 1.17A - Malaysia Aeronautical Search and Rescue Region



Source: International Aeronautical and Maritime Search and Rescue Manual Volume

Figure 1.17B - Malaysia Maritime Search and Rescue Regions

h) Kuala Lumpur Air Traffic Service Centre

The Kuala Lumpur Air Traffic Service Centre (KL ATSC) is headed by a Director and supported by two deputies - Deputy Director for ATSC and Deputy Director for KL TMA - and 243 ATCOs of various grades. The total number of the ATCO posts approved by the Government was 353. As of March 2014, there were 110 vacant posts.

The KL ATSC's Controller Working Positions (CWPs):

(i) Approach Control Surveillance

- TMA Supervisor
- Aproach North
- Approach South
- Approach Low
- Approach Radar (Flow Control)

(ii) Area Control Surveilliance

- Sector 1 Area Control Surveilliance
- Sector 2 Area Control Surveilliance
- Sector 3 Area Control Surveillance
- Sector 4 Area Control Surveillance
- Sector 5 Area Control Surveillance
- Sector 6 Area Control Surveillance (Sector 1 Upper)
- Sector 7 Area Control Surveilliance

(iii) Area Control Procedural

- Sector 1 Area Control Procedural
- Sector 2 Area Control Procedural
- Sector 3 Area Control Procedural
- Sector 4 Area Control Procedural
- Sector 5 Area Control Procedural

(iv) Sector Flight Data Assistant/Clearance Delivery

- Sector 1 Flight Data Assistant
- Sector 2 Flight Data Assistant
- Sector 3 Flight Data Assistant
- Sector 4 Flight Data Assistant
- Sector 5 Flight Data Assistant
- Sector 6 Flight Data Assistant
- Flight Data Processing
- Clearance Delivery
- Assistant Clearance Delivery
- Assistant Flight Information Services

(v) Working Positions (No Rating required)

- Watch Manager
- Controller-Pilot Data Link Communications
- Flight Information Services
- High Frequency/Aeronautical Mobile Services Station (HF/AMSS) South East Asia (SEA)1 and HF/AMSS SEA 2 Aeronautical Fixed Telecommunications Networks (AFTN) 1 and AFTN 2

(vi) Butterworth Terminal Area

To enable the Military to meet its national operational requirements, a number of control zones, training areas and danger areas have been established. Operational control of these airspaces and responsibility for the provision of air traffic services within these airspaces have been delegated to the military. Coordination procedures between the civil and military authorities have also been established as follows:

Provision of approach control service within lateral limits of Butterworth Control Zone:

- Ground/Sea - 5,500 ft. altitude - FL245,
- Elsewhere 2,500 ft altitude - FL245 with Butterworth Terminal Area.

Air traffic to/from the civilian Penang International Airport (PIA), Alor Setar Airport and Langkawi International Airport is provided by military ATCOs who have been licensed by the ATI Division, which develops and establishes the ANS safety standards and performs safety oversight and to ensure the provision of services to civil traffic. The rationale for such an arrangement is based on the military activities at Butterworth Military Airport (BMA) which is in close proximity to PIA, and other military activities carried out over the high seas in danger areas WMD 412A and WMD 413A (permanently established). Furthermore, the final approach segments of both the PIA and the BMA intersect. No major incident has been recorded with the present arrangement/delegation of authority.

6) Airworthiness Sector

The Civil Aviation Act of 1969 empowered the DGCA to exercise its statutory powers to regulate the civil aviation and airport services including the establishment of standards and its enforcement.

The Civil Aviation Regulation (CAR) of 1996 was derived from the United Kingdom Air Navigation Order (ANO) of the mid-nineties and adopted with certain provisions for the Malaysian requirements. The CAR Fifth Schedule - Aircraft Equipment and Sixth Schedule - Radio and Radio Navigation Equipment to be carried in aircraft, and the DGCA issued Airworthiness Notices (ANs) specifically AN. No. 1 - Aircraft Certification, forms the basis for aircraft airworthiness and design standard for acceptance into Malaysian registry.

A comprehensive review of the MCAR 1996 by consultants was carried out in March 2013 and the submission of the final report was completed in January 2014. It was anticipated that the introduction of the CAR 2016 would streamline the DCA regulatory functions on similar approach to the European Aviation Safety Agency (EASA) requirements. This would include the introduction of CASR (Civil Aircraft Safety Requirements, AMC (Acceptable Means of Compliance) and GM (Guidance Materials) as part of the Malaysian regulatory framework, requirements and procedures.

The Director of Airworthiness Sector reports directly to the DGCA and is responsible for the operations of five divisions, namely: Continuing Airworthiness, Engineering, Maintenance Repair and Overhaul (MRO), Licensing and Standards.

The primary functions of the Airworthiness Sector include surveillance oversight of the aircraft maintenance activities on scheduled and non-scheduled air carriers, MROs, and the licensing of Aircraft Maintenance Engineers (AMEs). The sector is also responsible for the management of the aircraft register and joint technical audits with the Flight Operations Sector and Air Transport Sector for the issue or renewal of Air Operating Certificate.

With respect to aircraft accidents or incidents investigation, officers with specific trade and specialisation may be called upon, to assist the Air Accident Investigation Bureau, which is under the Ministry of Transport.

The Airworthiness Sector has established a minimum qualification of a university engineering degree or an Aircraft Maintenance Engineer’s Licence (AMEL) for the posts of Airworthiness Engineers or

Airworthiness Inspectors respectively, and in addition, a minimum of five to seven years hands-on aviation industry experience. 37 of the 40 posts had been filled to support an 8% annual rate of growth of aircraft increment for the local air transport industry.

The Airworthiness Sector has developed a good working relationship with the local aviation organisations whereby, the newly recruited technical staff have been given the exposure to work closely with industry players. The DCA has made provisions in the AN. No. 1 Aircraft Certification, for the operator to bear the cost of training for DCA officers, specifically for the airworthiness engineers, inspectors and pilots for new aircraft type to be placed on the Malaysian register. This serves to keep them abreast with the latest development on the local airlines or operators fleet expansion programme.

The DCA Airworthiness Division Manual (ADM) provides guidance and procedures to airworthiness inspectors and airworthiness engineers to carry out their duties and function responsibilities.

The Sector emplaces a fairly comprehensive audit plan for the local and international organisations requiring DCA approvals. These approved organisations are subject to an annual audit. The audit includes local and international base maintenance and line stations. These audits may be scheduled on mutual arrangement with the organisation or be carried out on an opportunity basis when the DCA officers are in the vicinity of that organisation during the auditing period.

Any audit findings or deficiencies will be recorded in the NCRs (Non-Conformance Reports) and categorised into the respective levels of Level 1, Level 2 or Level 3. The Level 1 NCR requires urgent and mandatory compliance to a major deficiency in the audit findings. The Sector would review the corrective actions and reschedule an audit of the organisation before closing the finding as acceptable.

The ANs are published on a regular basis in the DCA website and would serve to notify any current changes on airworthiness policies or requirements for the Aircraft Maintenance Engineers and the aviation organisations to comply with as applicable. Some of the Airworthiness Notices issued by the Airworthiness Sector may originate from Original

Equipment Manufacturers' (OEMs) service bulletins or in-service difficulties arising from incident or accident reports which may affect aviation safety. The Airworthiness Notices form part of the Malaysian regulatory framework and the expedient means for the aviation industry to comply with at short notice.

The AN. No. 11 - Mandatory Occurrence Reporting, requires Air Operators and Maintenance Organisations to transmit information on faults, malfunctions, defects and other occurrences which cause or might cause adverse effects on the continuing airworthiness of the aircraft to the DCA.

With respect to ICAO Annex 19 - Safety Management, the Airworthiness Sector has implemented the requirement under AN No. 101 - Safety Management Systems (SMS) For Approved Maintenance Organisation (AMO) including Approved Training Organisations (ATOs) in March 2008. The SMS was made effective on 01 January 2009.

The Sector has been actively involved in the audits of 176 local and international Approved Maintenance Organisations (AMOs) that hold the DCA approvals; continuing airworthiness surveillance of 892 aircraft (of which 839 aircraft are active in operations), 12 Approved Training Organisations (ATOs) for Aircraft Maintenance Engineers and Technicians ab-initio training and also aircraft type training programme. There were 4,212 Licensed Aircraft Maintenance Engineers issued with DCA licence, but 2,374 licensed holders remain current. CAR 30 requires that inspection, overhaul, repair, replacement and modification works on a Malaysian-registered aircraft, including the engines, propellers and aircraft components, are carried out by an approved person or organisation, specifically, under the AMO maintenance organisation exposition procedures. The DCA requires the release of an aircraft 'Certificate of Release to Service' to be issued by an approved or authorised personnel, type-rated on the aircraft type under a DCA approved AMO procedures. The introduction of the new CARs would also address the training requirements and certification responsibilities of both Aircraft Maintenance Engineers in Category B and Aircraft Maintenance Technicians in Category A in their respective trades. The DCA Malaysia Part 66 engineers and technicians licensing system is based on the EASA Part 66 syllabus and training requirements.

7) Flight Operations Sector

The Director of Flight Operations reports directly to the DGCA and is responsible for the operations of five divisions, namely:

- Flight Crew Licensing,
- Air Operator Regulatory,
- Flight Simulator,
- General Aviation, and
- Flight Calibration.

The primary functions of the Flight Operations Sector include surveillance oversight on scheduled and non-scheduled air carriers, flight test and simulator training of pilots, flight crew licensing on examinations standards, General Aviation activities, airfields and airways calibration and the conduct of a joint technical audit with the Airworthiness Sector and Air Transport Sector for the issue or renewal of Air Operating Certificate (AOC) for scheduled and non-scheduled air carriers. With respect to aircraft accidents or incidents investigation, pilots from this sector may be called upon, to assist the Air Accident Investigation Bureau, under the Ministry of Transport.

The Sector has established the procedures for Mandatory Occurrence Reporting (MOR) Scheme Guidelines in the Flight Operations Notice for the air operators to comply with in DCA Malaysia website.

With respect to ICAO Annex 19 - Safety Management, the Flight Operations Sector had implemented the requirement under the Aeronautical Information Circular (AIC) No: 06/2008. In conjunction with ICAO Annex 6 Part 1 Chapter 3 paragraphs 3.2.3 and 3.2.4 and Part III Chapter 1 paragraphs 1.2.3 and 1.2.4 with effect from 1 January 2009, it requires all Malaysian AOC Holders to implement an integrated Safety Management Systems (SMS).

To date, 8 of the AOC Scheduled Operators have complied with the SMS requirements and approved by the Sector. The implementation of the SMS for the 16 Non-Scheduled Operators is being incorporated in stages.

The following documents form part of the sector procedure manual in carrying out their surveillance responsibilities:

- Flight Operations Surveillance Inspector Handbook,
- Flight Crew Licensing Handbook,
- Flight Operations Policy, and
- Procedure Manual and Ramp Inspection Handbook.

As stated in the authorised Flight Examiner Handbook, each flight examiner is required to conduct at least six instrument flight checks and two type rating checks over the three-year period of their authorisation. In addition, they have to submit a quarterly activity report. In accordance with the Handbook, the authorised examiner has to pass an initial test upon appointment and a renewal test, to be conducted six months prior to the expiration of the authorisation. In between the tests, the examiner will also be the subject of one observation session to be conducted by the inspector.

The present activities of the Flight Operations Sector for surveillance oversight includes 8 Scheduled Operators, 21 Non-Scheduled Operators 8 Approved Flying Training Organisations, 16 new AOC applicants, 12 Flying Clubs, international flight en-route Inspections, domestic and international Station Facility Inspections and Ramp Inspections.

The frequency for Station Facility is once in every 2 years, the RAMP Inspection is 4 inspections at every originating en-route or destination stops, 4 inspections annually at every location but may depend on the safety performance of the operator while Base Inspection for Scheduled Operations and Non-Schedule Operations to be carried out on annual basis.

The Sector has a total establishment of 28 pilot posts to manage the various divisions, and of which only 16 posts had been filled. The need for experienced pilots to fill up the various posts had been an issue for most authority bodies worldwide, unless better incentives are offered.

1.17.2 Malaysia Airlines

1) Introduction

Malaysia Airlines (MAS) began in 1937, when the Straits Steamship Company and Imperial Airways formed Malayan Airways Limited (MAL) in Malaya. MAL evolved through many changes to Malaysia-Singapore Airlines (MSA) until Singapore gained its independence in 1965, where its Malaysian part became Malaysian Airline System (MAS) Berhad. In 1987 the Company took the commercial name of 'Malaysia Airlines' in line with the international promotion of the country.

MAS held an Air Service Licence (ASL) and Air Operators Certificate (AOC) for scheduled and non-scheduled operations. It was public-listed in 1985 with the Government holding a golden share. At its peak, MAS had an extensive network of operations with more than 100 destinations spanning over 5 continents around the world. The recession in 1994 affected the airline's business significantly when its operations were drastically scaled down.

The airline's performance for the past years had been a subject of great interest as it had suffered financial losses. Competition from emerging low-cost operators significantly contributed to the negative performance of the Company. MAS had in its fleet the A380, A330, B747-400, B777-200ER, B737-400 and B737-800. Its subsidiaries Firefly & MASWings operated the ATR-72 plying most of the domestic network in Peninsular and East Malaysia.

In spite of its scaled-down operations it was still a fairly large organisation (*Figure 1.17C* [below] shows the *Organisation Structure of MAS*), with a staff strength of more than 20,000 employees. It was headed by a Group Chief Executive Officer (CEO) who reported to the Board. Eight Directors reported to him, each heading a Division. The Divisions were, as follows:

- Group CEO Office
- Commercial
- Operations
- Corporate Services
- Customer Services

- Finance
- Human Resources
- MAS Aerospace Engineering (Engineering & Maintenance Division)

2) Engineering & Maintenance

a) Organisation Structure

The Engineering & Maintenance Department (EMD), also known as MAS Aerospace Engineering, was headed by a Chief Executive Officer (CEO), assisted by a Deputy CEO (Airlines Operations) and Senior Vice President (SVP) MRO Operations. The Finance, Engineering Materials, Business Support, Business Development, Legal and Warranty departments of the EMD reported direct to the CEO of the EMD. Heavy Maintenance, Engineering, Commercial, Training, Special Project, Engineering Facility and Workshop departments reported to the SVP (MRO Operations). The Technical Services, Maintenance Operations, Aircraft & Engine Maintenance Planning, Quality Assurance, Aircraft Project, Lease Planning, End-of-Lease (EOL)/Airline Engineering Group (AEG) Special Project and EOL Project Departments reported to the Deputy CEO (Airlines Operations). The organisation’s management structure encompassed all the relevant areas befitting a maintenance management and maintenance organisation and was manned by suitable and experienced personnel. Key positions (post holders) as required for the Air Operators Certificate (AOC) holder and maintenance organisation were nominated by MAS and approved by DCA Malaysia. These key positions were further supported downstream by departmental managers and their executives.

b) Maintenance and Design Approval

The EMD was responsible to manage and carry out the maintenance of the MAS fleet of aircraft, which consisted of B747-400, B777-200ER, B737-400, B737-800, A330 and A380. The Maintenance and Management approval was issued by the DCA Malaysia in 1971. The approval was based on the approved quality

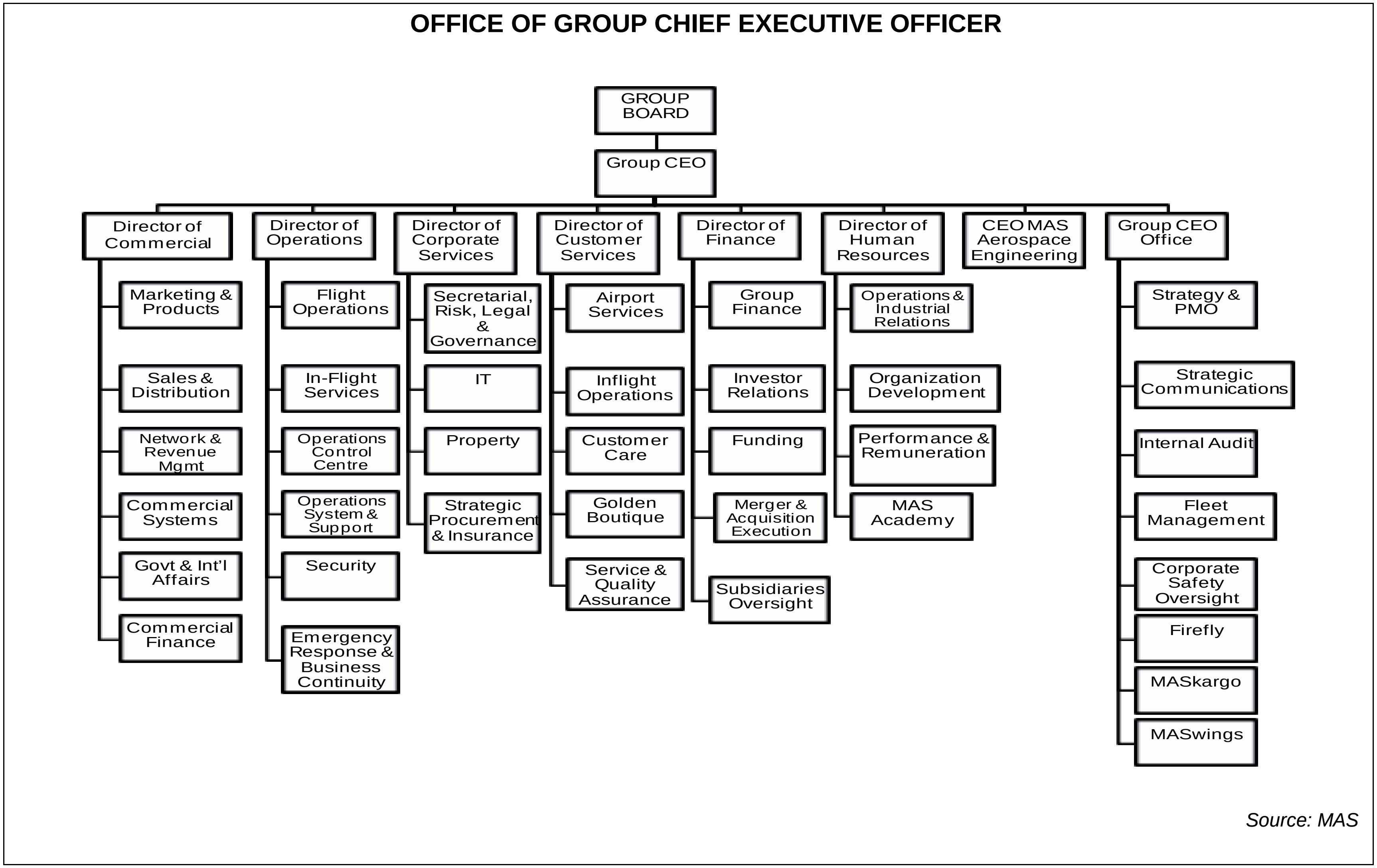


Figure 1.17C - Organisation structure of MAS

system laid out in the Maintenance Management Organisation Exposition (MMOE). The quality management system as detailed in the MMOE was under the responsibility of the Head of the Quality Assurance, who had direct access to the CEO of the EMD.

In the quest to undertake third party maintenance business the EMD also carried out maintenance of foreign registered aircraft under their respective National Aviation Maintenance Organisation Approvals. These approvals are from the European Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA) of the United States of America (USA), the Civil Aviation and Safety Authority (CASA) of Australia and others. All these approvals had their independent approval process of initial approval, revalidation and surveillance.

The oversight of these maintenance activities was by regular audits and surveillance by the internal auditors of the Quality Assurance department and by DCA Malaysia, as well as the National Aviation Authorities of the various countries whose aircraft were maintained by MAS. In some cases, the audits were also carried out by the respective customers. There have not been any findings significant enough for any regulatory actions to be taken against the EMD for issues arising out of aircraft maintenance.

The EMD was also issued with Design Organisation Approval by DCA Malaysia. This allows the EMD to make minor design changes on the MAS fleet. To administer this, a team of engineers in the Technical Services Department of the EMD were qualified and approved in the various aviation disciplines such as Structures, Systems and Avionics.

c) Training

The EMD had its own Training school which provided ab-initio training to qualify selected candidates to obtain the DCA Malaysia Maintenance Engineers' licenses in the Mechanical or Avionics category. There were also training programmes for aircraft and workshop technicians as well as approval holders. The Training School also provided continuation training which was required for all staff working on aircraft and in workshops, and in addition, aircraft type training and training for external parties. The training requirements were laid down in the DCA Part 66, which is similar to the EASA Part 66 requirements.

d) Base Maintenance

The EMD had two main bases for base maintenance: KLIA in Sepang and Subang Airport (SZB) in Subang.

The Kota Kinabalu (BKI) base in Sabah was an extension of the KLIA base. These bases were equipped with the hangars and facilities as required in the scope of the approval. The SZB base had 4 hangars to accommodate all aircraft in the MAS fleet. The SZB facility also accommodated all the support workshops for the required maintenance. The KLIA base had 2 hangars, one of which could accommodate the A380-800. The KLIA base had some limited support workshops for maintenance activity under the scope of approval. The BKI, extension of KLIA, had one smaller hangar only capable to accommodate B737 series aircraft or its equivalent.

e) Line Maintenance

Other than the main bases, there were also line stations according to the regions around the world. These were, as follows:

- Peninsular Malaysia,
- Sabah and Sarawak,
- South East Asian,
- Far Eastern,
- America and Pacific,
- Australian and New Zealand,
- Indo-Pakistan/Mideast and African, and
- European.

Line maintenance of aircraft at international line stations was contracted out to the local maintenance organisations. These line maintenance organisations were approved by DCA Malaysia before they took over the task. The organisations were also subjected to regular audits by MAS and DCA Malaysia.

f) Maintenance Authorisation

The EMD had approximately 4000 staff; distributed among the SZB base, KLIA base and the BKI extension base. There were approximately 1240 certifying staff at both SZB and KLIA bases and 41 certifying staff in BKI. The certifying staff consisted of the following:

- Licenced Aircraft Maintenance Engineers,
- Workshop approval holders,
- Certifying mechanics,
- Stores Inspectors,
- Non Destructive Testing (NDT) approval holders,
- Welders.

Authorisation of certifying staff for aircraft and component maintenance was carried out by the EMD's Quality Assurance department. This was strictly in accordance with the requirements laid down in the MMOE. These requirements, which were in line with the EASA requirements, were approved by DCA Malaysia. This process of authorisation was subjected to internal audit by independent quality auditors within the organisation, as well as by the DCA and other National Aviation authorities.

The Head of Quality Assurance (QA) was responsible for the administration and control of the Certifying staff.

g) Safety Management System

The EMD had implemented the Safety Management System as documented in the Safety Management Manual and as required by DCA Malaysia Airworthiness Notice No. 101. This safety management was a part of the Company-wide Corporate Safety Management led by the Corporate Safety Oversight department which reports to the Group CEO's office. There was an internal reporting system in place for occurrences and hazards which encompassed provisions for confidential reporting. Regular safety meetings were conducted within the organisation as well as representing the division within the overall corporate system. Safety Management was supported by Occupational Safety, as required by the Occupational Safety and Health Act 1994. Safety actions were deliberated during these meetings and mitigating actions were discussed and followed up.

3) Operations

This division was headed by the Director of Operations and supported by Flight Operations, In-flight Services, Operations Control Centre, Operations System & Support, Security, and Director of Operations Office.

a) Flight Operations

The structure consisted of 6 Senior Managerial positions namely Quality Assurance & Regulatory Affairs, Training & Standards, Flight Safety & Human Factors, Technical & Development, Crew Planning & Deployment and Line Operations.

i) Flight Operations Management

The Flight Operations Management Structure *(Figure 1.17D* below*)* met the Air Operators Certificate (AOC) requirement as stipulated in the MCAR 1996. The key post holder positions in MAS were manned by captains who possessed outstanding credentials, senior in rank and had held several aircraft type rating in the airline's fleet. Their extensive exposure was therefore an asset to the airline's operations.

MAS Operations Manual A, Part 1.4.11 defined the guidelines for management pilots' office coverage and flying duties. As an example, the guideline stipulated that a Flight Operation

Manager (FOM) would be rostered 9 days flying duties (excluding weekend) and 13 days on office duties.

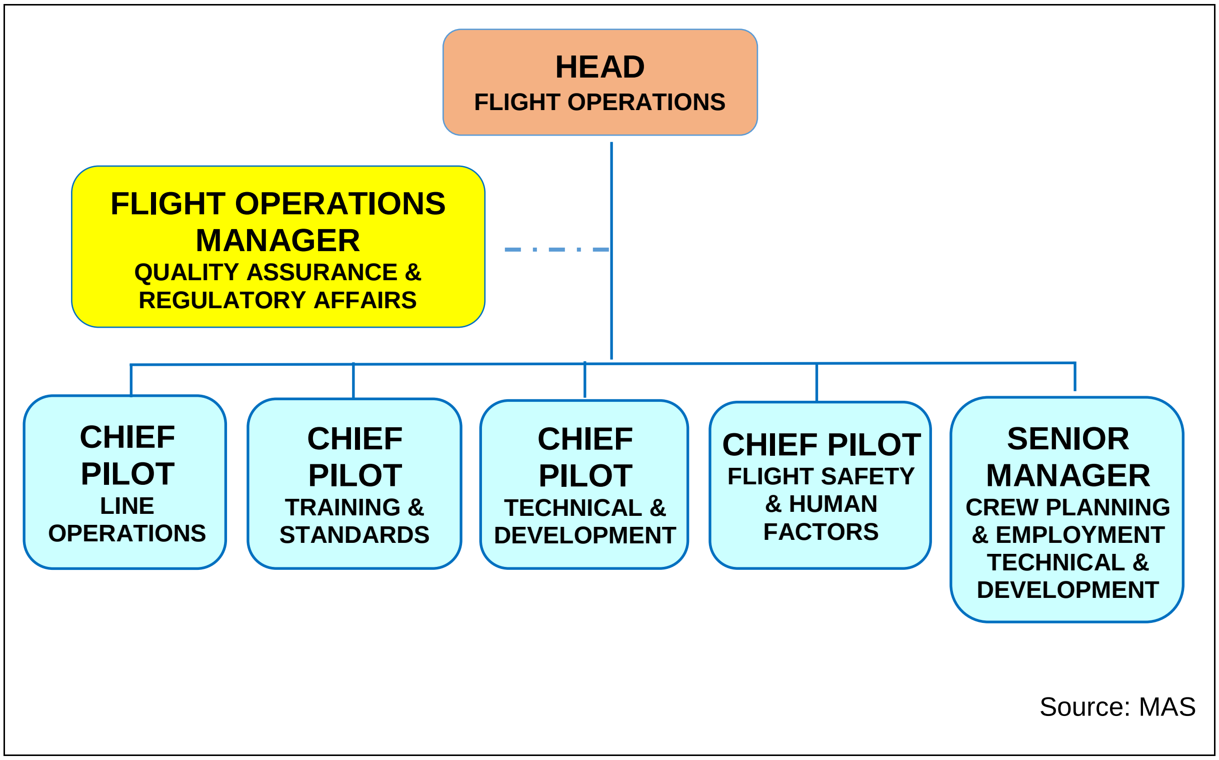


Figure 1.17D - Organisation of Flight Operations Management

ii) Organisation and Management related to B777 Operations

All the fleets in the Company were under the purview of Chief Pilot Line Operations. The fleet was headed by a Fleet Manager B777 who would report to the Chief Pilot Line Operations. The Fleet Manager B777 had been with the Company for the past 17 years and until March 2014 the fleet comprised of 17 aircraft. The Fleet Manager (with more than 10 years Command experience on the B777) was supported by non-flying staff in the day-to-day management of the fleet co-ordinated by Flight Operations Controllers (*Figure 1.17E* [below]).

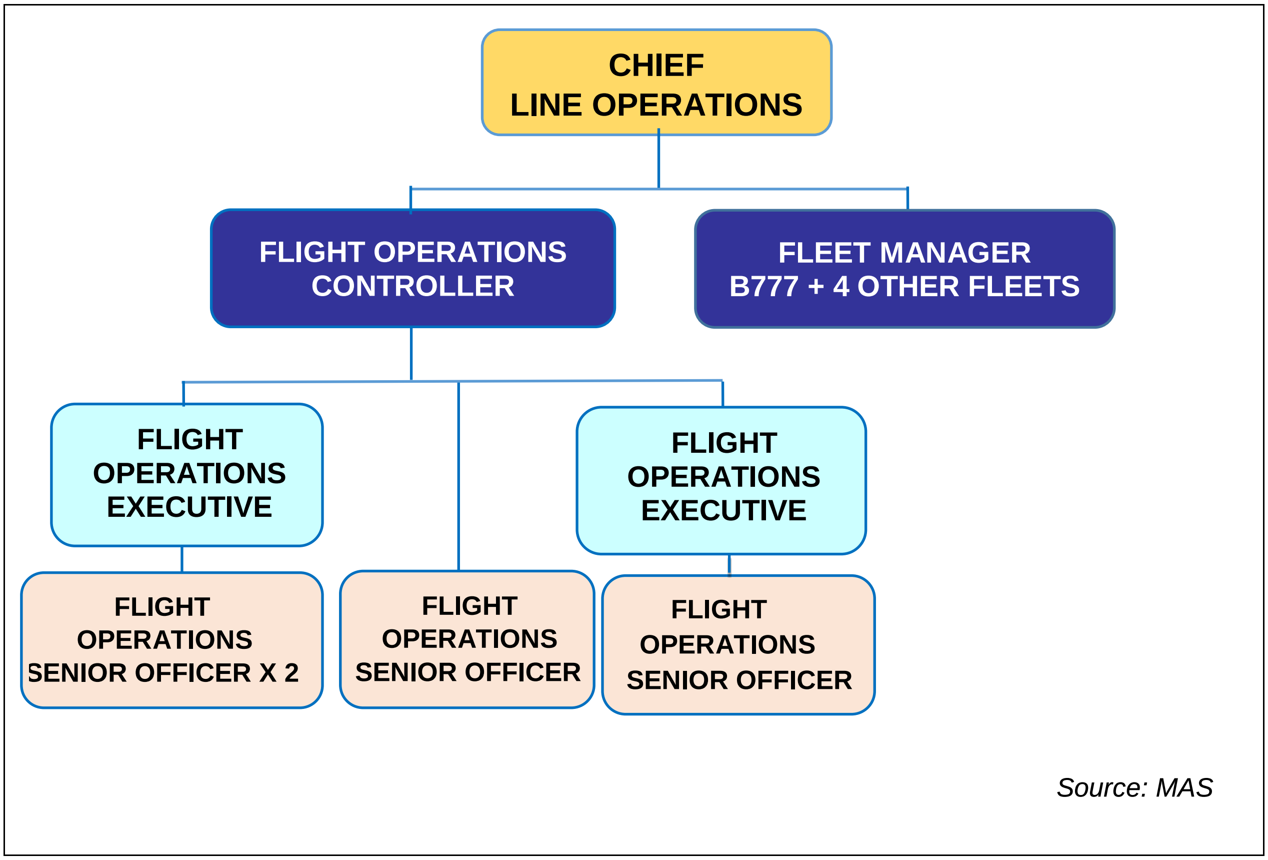


Figure 1.17E - Line Operations, Administration & Support (as of January 2014)

iii) Technical Crew

The airline technical crew were pioneered by pilots who crossed over to MAS when the then Malaysia-Singapore Airlines (MSA) split in 1972 to become MAS and SIA respectively. In the early days of MAS up to the mid-1980s a majority of MAS pilots came from MAS-sponsored cadets. These trainee pilots were normally sent to reputed Flying Colleges/Academies, mainly in Australia, Philippines, Scotland and Indonesia. These candidates were put through stringent pre-hire recruitment processes which included aptitude tests, psychomotor skills, as well as interviews by a panel comprising of Management Pilots and Human Resource Managers and/or Executives. In later years, the process became even more stringent with the inclusion of simulator evaluation and psychological tests.

After the mid-1980s, the emergence of local flying schools had resulted in most of the sponsored cadets undergoing their basic training in Malacca at the Malaysian Flying Academy (MFA). The MFA had also provided training for foreign students from Singapore, Indonesia, Bangladesh and India. This had benefited MAS in terms of costs and the ability to graduate ab initio qualified pilots in a shorter time compared to overseas flying schools.

In the last ten years, more flying colleges or academies were set up, such as in Kota Bahru and Langkawi. MAS-sponsored cadets were eventually trained at these places in tandem and then absorbed as trainee pilots into MAS, including a small number of self-sponsored students who made the grade. These cadets would pass out with a Frozen ATPL (Air Transport Pilot Licence) and by the time they had accumulated a total of 1,500 hours or more, the full authorisation of the licence would take effect giving the holder the privilege of its full coverage.

From the early days of operations, MAS started with domestic and regional services. Thus, the fleet of aircraft had always included small propeller aircraft to service remote towns that were equipped with short field aerodromes and short-haul twin engine jets. Generally, a career of a pilot in MAS began as a co-pilot on the smallest Turbo Props, or sometimes when the demand and the promotion was rapid, suitable candidates would be posted direct to the B737 upon entry into the airline. A co-pilot would need to serve for at least 5 to 7 years in the Company on the lower fleet before one could be considered for promotion to the B777. Before the arrival of the new generation aircraft, the career progression would start with the F27/50, then the 737 classics as their first jet aircraft experience, then to either A300B4 or the DC10/B747-200. After the introduction of the new generation aircraft, they were normally promoted from the B737/200/400/800 to the A330 or B777 fleet then the B747-400/A380 depending on the Company's individual fleet requirement.

The pilot promotion policy had since changed to include individual pilot's bidding for promotion to larger aircraft, which was not the case in the past.

The pre-hire test also applied to those joining the airline with previous flying experience from other flying organisations. A significant percentage of MAS pilots came from the Royal Malaysian Air Force (RMAF), mainly those who had served the Air Force as short-commissioned officers. After about seven to ten years of service in the RMAF, they were able to join MAS with recognised flying hours and experience to be accepted as First Officers in the lowest fleet. After accumulating sufficient airline flying hours, they would be ready for promotion to Captain on the lowest fleet, e.g. F27/50, or direct to the B737 jet. A small percentage of pilots came from a general aviation background and needed to go through the similar stringent pre-hire process before commencing their training to the appropriate fleet.

On the average it would take at least 15 years of flying in the Company before a pilot could be promoted to command the B777. Among the factors for career progression is eligibility in terms of total command hours, base check and line check competencies, seniority in the pilot ranking and the airlines expansion plan. In Malaysia Airlines, no young fresh ab-initio pilot would be posted direct to the big wide-body jet (i.e. B777) without the smaller twin jets experience. By the time a captain was ready for the B777, he would have at least flown F50, B737 or A330 or combination of all the 3 aircraft with at least a total of 5,500 hours, part of which had to be a minimum of 1,500 command hours and 2 years operational on the MAS B737.

By normal career progression, the Captain that was flying on this aircraft would have met the full pre-requisites to be on the elite fleet of the B747-400 or the A380. However, it was his choice that he preferred to remain on the B777 fleet as he did not bid for position on the two higher fleets.

iv) Technical Crew of MH370

The PIC of MH370 graduated in May 1981 from the Philippines Flying School under the MAS sponsorship programme during that era. He started his career with MAS upon graduation and served MAS until the day of the eventful flight.

The FO of MH370 graduated from the Langkawi Aerospace Training Centre (LATC) on the Island of Langkawi, Kedah, Malaysia in June 2007. LATC has been in existence for the last 12 years. MAS had sponsored at least ten batches of pilots at an average of 12 trainees per batch. These graduates had been flying with MAS upon graduation. Graduates from LATC generally met the standards set by MAS, proven by the numbers joining the airline as trainees and eventually becoming qualified First Officers. Since the last 5 or 6 years there were also pilots being sponsored and trained in the Asia Pacific Flight Training (APFT) Kota Bahru, one of the latest additions to the number of flying schools available locally.

The fleet carried sufficient numbers of Type Rating Examiners (TRE) and Type Rating Instructors (TRI) to fulfil the licensing requirements. TRE and TRI were Captains from within the airline, appointed with approval from the Licensing Section of the DCA. They were also tasked with monitoring the overall standards to be maintained by the fleet. This responsibility is under the jurisdiction of the Training and Standards Department, which is headed by a Chief Pilot. On the day of this eventful flight, the Captain was conducting the last phase of the Co-pilot's training as a B777 First Officer, in the capacity of a TRE.

v) Working Schedule/Roster Schedule and Management

The working schedule and rest requirement to manage crew fatigue was highly regulated and normally bounded by guidelines stipulated by the CAA UK CAP 371 and the Malaysian Civil Aviation Regulations (MCAR) 1996. The MCAR 1996 adapted the CAA CAP 371. With the formation of the Joint Aviation Requirements (JAR), DCA Malaysia had gradually migrated towards regulations stipulated in the JAR. Duty and Flight Time Limitation (FTL) was strictly guided by these published regulatory documents. In general, MAS has since its inception, adopted a more stringent and restrictive FTL based on the Memorandum of Understanding (MoU) between the Pilots Association and the adequately rested before they were scheduled to any assigned flight duties. The Pilots Association played an important role to ensure compliance to the limits were met.

In the case of MH370, the expected flight and duty time was less than 8 hours, with a single leg of one take-off and one landing. The Regulatory requirement and MAS Operations Manual A, Part 7.1.20 and MoU would only require one set of crew to man the flight. Standard Company’s practice, in compliance with FTL, would call for the whole set of crew to be allocated a stop-over duration of 24 hours (more than the minimum rest period required) in Beijing before returning to Kuala Lumpur. Beijing was a destination that MAS operated with the same aircraft type on a daily basis.

The guidelines for Technical Crew complement requirements based on Maximum Schedule Block Time were as follows:

- Less than 8 hours: 2 crew (1 Captain and 1 Co-pilot);
- Between 8 to 12 hours: 3 crew (2 Captains and 1 Co-pilot); and
- More than 12 hours (3 Captains and 2 Co-pilots).

The Technical Crew were required to undergo medical check-up by approved aviation doctors for their license renewal. The medical certificate issued forms part of the validity of a pilot flying license.

A summary of the work schedule for the PIC and the FO, three months prior to the eventful flight, is available in *Table 1.17A* (below).

Rank	**24**	**72**	**7**	**28**	**90**	**SEP Validity**
	Hours		**Days**			
Pilot-in-Command	0:00:00	7:00:00	20:39:00	91:04:00	303:09:00	14 May 2014
First Officer	0:00:00	0:00:00	28:47:00	51:17:00	158:46:00	26 July 2014

Table 1.17A - 3 Months FTL Data

vi) Safety Management System

MAS Safety Management System (SMS) had been designed to comply with the framework as per ICAO in Annex 6, Appendix 7 (Currently Annex 19), Framework for Safety Management Systems and the expanded guidance found in the ICAO Doc.9859 Safety Management Manual (SMM) and IATA SMS Implementation Guide. In addition, this system was consistent with the requirements of the DCA Malaysia's Aeronautical Information Circular (AIC) document number 06-2008: SMS. MAS had established these requirements to ensure positive control and continuous improvement for safe and secure operations, including the operations of its subsidiaries, MASWings, Firefly, MAS Aerospace Engineering and MASkargo. This document had formed an integral part of the Corporate Safety Policy Manual.

The SMS encouraged an open reporting policy or commonly referred by industry as non-punitive reporting system. This assured employees that reports of unpremeditated or inadvertent errors would not result in disciplinary or punitive action being taken against the reporter or other individuals involved. Employees were–assured that the identity, or information leading to the identity, of any employee who reported an error under this policy was never disclosed unless agreed to by the employee or required by law. The Open Reporting Policy encouraged individuals to report hazards and operational deficiencies to management. It also assured personnel that their candid input was highly desired and vital towards safe and secure operations.

The organisation had a proactive reporting system in place. Refer to *Figure 1.17F* (below):

- The SMS' guidelines resided in the Corporate Safety Manual. There were various reporting channels for the staff to transmit safety-related reports to account holders or their designates;
- The reporting channels were well-structured and covered all areas of operations:
  - Air Safety Report (ASR)
  - Cabin Safety Report (CSR)
  - Ground Safety Report (GSR)
  - Hazard report (Hazard/HZR)
  - Confidential Human Factors Incident Report Programme (CHIRPs); and
  - Flight Operations Quality Assurance (FOQA).

vii) Confidential Human Factors Incident Report

The flight crew and cabin crew were constantly being encouraged and reminded to utilise this reporting channel during their CRM and Safety classes (refer *SEP Manual; Part 7.15.2*). The Confidential Human Factors Incident Report (CHIRP), (refer to *Table 1.17B* [below]*)*, being a highly confidential report, had become the most appropriate tool for identifying potential human factor issues, especially on the behavioural patterns of flight and cabin crew.

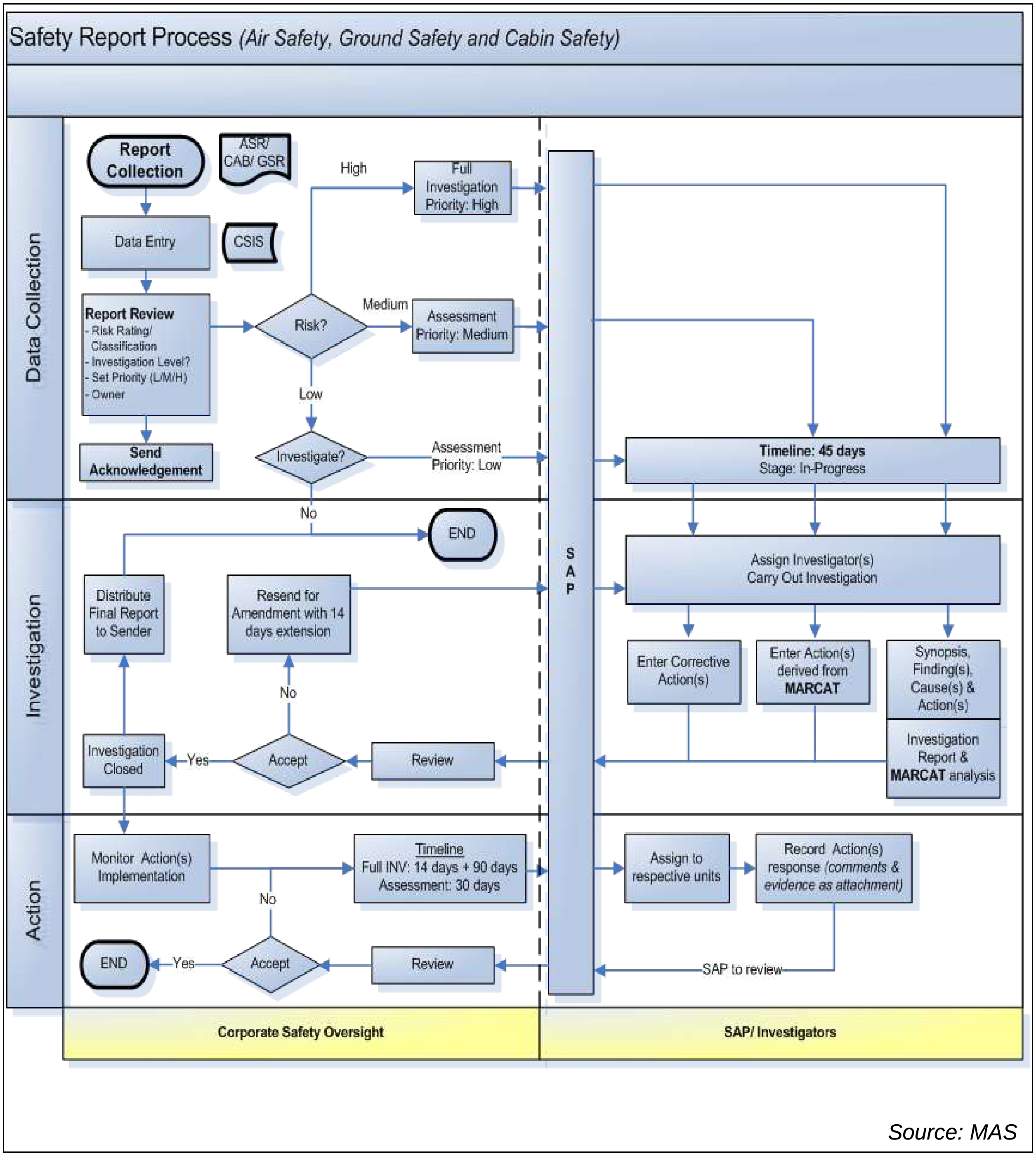


Figure 1.17F - Safety Report Process

	Year 2013				Year 2014		
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
CHIRPS	**4**	**-**	**2**	**-**	**-**	**-**	**-**
10 September 2013	Communication issues between Tech Crew and Cabin Crew (1 report received)						
23 September 2013	Cabin Crew to be offloaded by Tech Crew (3 reports received)						
15 November 2013	Mis-communication between Technician and Cabin Crew during ground servicing (2 reports received)						

Table 1.17B - List of CHIRPs 2013 & 2014

viii) Flight Operations Quality Assurance

The airline had acknowledged the importance of safety as its utmost priority. Like most other airlines, with statistics showing Human Factor as the main contributor to air accidents, the Flight Operations Quality Assurance (FOQA) programme was introduced. This system had contributed tremendously even in non-eventful cases where impending trend towards an unsafe situation could be recorded. With this system in place investigations of events that could lead to an incident would be undertaken and remedial actions and recommendations put into place.

The FOQA programme was introduced in 2010. The objective of FOQA was to promote safety and accident prevention by identifying operational safety trends during normal line operations.

MAS considered FOQA as an important safety reporting culture where safety is enhanced in a non-punitive manner (reference: *MAS Operations Manual A, Part 2.2.4.2*). FOQA protocol, a written document under the custody of the Flight Safety and Human Factor Department (dated 07 July 2010) stipulated manners at which corrective and timely strategies were implemented following a risk or potential hazardous trend.

The statistics of FOQA events in the last 2-year period (April 2012-March 2014) is as in *Table 1.17C* (below).

ix) Line Operations Safety Audit

The Line Operations Safety Audit (LOSA) was first introduced in 2004 in collaboration with the University of Texas, USA. The results were fruitful, and recommendations were implemented via Safety Change Process (SCP). MAS conducted LOSA every 2 years but not later than 5 years. LOSA was conducted by taking random samplings of all aspects of operations including random audit of normal scheduled commercial flights.

The last LOSA (2nd LOSA) was carried out between March and August 2011. The objective of LOSA was for MAS to diagnose its level of resilience to systemic threats, operational risks, and front-line personnel errors, thus providing a data driven approach to prioritise and implement actions to primarily enhance safety. This was carried out system-wide with no emphasis on any specific fleet.

x) Crew Resources Management

MAS considered Crew Resources Management (CRM) as a critical component of flight safety during operations and introduced it more than 20 years ago. The training programme for the pilots included the Cabin crew & Dispatchers. For new recruits there was a 3-day programme for CRM. Recurrent training was conducted on a yearly basis. The Safety Awareness Programme (SAP) conducted on a yearly basis would include the recurrent for the CRM training/ refresher. This programme had been in the system ever since the release of ICAO Annex 6 Part 1.

It started off with the pilots only to improve the cockpit culture. It was considered essential then as the airline had

Flight Operation Quality Assurance (FOQA) data statistic 2 years before the incident date.

i. Number of Triggers
ii. Total numbers of flight.
iii. percentage of trigger

Rate per 10,000 flight cycles			2012									Year 2013												Year 2014		
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Flight Cycles		798	780	789	811	813	785	817	852	799	836	672	809	779	842	837	826	812	659	684	792	811	837	772	831
2	UA	#	1	-	3	1	1	1	1	-	3	1	-	1	1	-	-	1	4	2	2	1	3	-	1	3
		Rate	12.53	-	38.02	12.33	12.3	12.74	12.24	-	37.55	11.96	-	12.36	12.84	-	-	12.11	49.26	30.35	29.24	12.63	36.99	-	12.95	36.1
3	Hard Landing	#	2	-	1	-	-	-	1	-	-	1	-	1	1	1	2	1	-	1	-	1	-	2	2	-
		Rate	25.06	-	12.67	-	-	-	12.24	-	-	11.96	-	12.36	12.84	11.88	23.89	12.11	-	15.17	-	12.63	-	23.89	25.91	-
4	Long Flare	#	9	19	11	8	10	7	13	9	10	7	10	9	11	17	15	17	10	9	10	11	8	10	7	7
		Rate	112.8	243.6	139.4	98.64	123	89.17	159.1	105.6	125.2	83.73	148.8	111.2	141.2	201.9	179.2	205.8	123.2	136.6	146.2	138.9	98.64	119.5	90.67	84.24
5	Late Land Flap	#	1	-	2	-	2	-	1	-	2	1	-	-	1	-	-	1	1	-	-	1	-	-	-	-
		Rate	12.53	-	25.35	-	24.6	-	12.24	-	25.03	11.96	-	-	12.84	-	-	12.11	12.32	-	-	12.63	-	-	-	-
6	Winshear	#	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
		Rate	-	-	-	-	-	-	-	-	-	-	14.88	-	-	-	-	-	-	-	-	-	-	-	-	-
7	TCAS	#	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	2	2	-	-	1	2
		Rate	12.53	-	-	-	-	-	12.24	11.74	-	-	-	-	-	-	-	-	12.32	15.17	29.24	25.25	-	-	12.95	24.07

Source: MAS

Table 1.17C - Statistics of FOQA Events in the Last 2-Year Period (April 2012-March 2014) significant numbers of expatriate community serving MAS from a diverse culture. Later, the training programme also included Cabin crew & Despatchers. For new recruits there was a 3-day programme for the Initial CRM. Recurrent CRM training (1 day) also known as Safety Awareness Programme (SAP) was conducted regularly to cater for flight crew, cabin crew and flight despatchers. JAR-OPS Subpart N, JAR-OPS 1/3.965 stated that all major CRM topics should be covered every 3 years for technical crew, every 2 years for cabin crew and annually for flight despatchers.

xi) Training and Standards

MAS managed its entire training requirement in-house including the mandatory requirement for the flight crew. MAS had its own Training Centre for pilots as well as engineers. It was equipped with various Full Flight Simulators for all the fleet in the Company with most of the Flight training devices certified to FAA Level D, capable of zero flight time training. This Training Centre had been established for more than 40 years and had been certified by many countries as an approved Type Rating Training Organization (TRTO.)

Type Rating Instructors (TRI) & Type Rating Examiners (TRE) normally came from within the airline and they require stringent training and check before being approved by the DCA Licensing Division. Besides the availability as a TRTO, the Simulators were utilised by neighbouring airlines and smaller organisations within the region to fulfill their training and checking requirements.

Competency of pilots, as per regulatory requirements worldwide, is normally monitored every 6 months. MAS training policy required 2 Simulator sessions every 6 months. The two training sorties every 6 months consisted of 1 review and training followed by proficiency check session.

xii) MAS B777 Training and Standards

The training package for the B777 conversion training followed the Boeing Training Recommendations. During the introduction period, representatives from the Boeing Flight Training Department oversaw the operations. The first crew trained by Boeing comprised a project team of four pilots from the Company and one representative from DCA, the regulatory authority. The team members were then responsible for managing the introduction of the new aircraft into operation. Part of their responsibility was to ensure that the subsequent training and recurrent requirements were addressed according to the recommendations of the aircraft manufacturer, consistent with the mandatory requirements of the DCA Licensing Authority. When the B777 was introduced, the simulator was also procured, and it arrived at the MAS training premises before the first aircraft entered into commercial service. At the introduction phase of the B777 into MAS, the airline had sought assistance from the Boeing Flight Training Department to kick-start the training of new pilots locally.

In MAS, all aircraft purchased came with a package that included the respective simulator, except the B747-200/300 and Fokker F27. Like most other established airlines, MAS considered training as vital tool to maintain good pilot skills and standards.

The pilot's upgrade policy of having to serve on the smaller fleets at point of entry helped in preparing captains and co-pilots to handle larger machines, such as the B777. During the day of the event, the co-pilot was on his last training flight before he was due for a check flight on his next flight duty assignment. The Team had recorded that the FO was assigned to be the flying pilot for Kuala Lumpur/Beijing sector on the ill-fated flight.

Throughout a pilot's career, should the pilot's performance during Simulator and Line operational checks fell below the minimum standards, the Company would provide adequate retraining to ensure the required regulatory competency was maintained.

It is important to note that there were 3 phases of training when a pilot was undergoing conversion training to a new fleet in MAS. The FO's last fleet was the A330 and he was undergoing the final phase of training to be qualified as a co-pilot on the B777. The three training phases were:

- Ground School & Computer Base Training (CBT);
- Simulator Training; and
- Initial Operation Experience (IOE) Phase 1 and Phase 2.

The IOE was for the trainee to be trained during line operations on a passenger scheduled flight commanded by a TRE or TRI-qualified Captain.

During the initial part of the IOE, it was the Company's policy that the flight had to be accompanied by an additional experienced co-pilot or captain to support the flight in case the trainee needed any supervision and, most importantly, if the TRE or TRI was incapacitated. This policy guaranteed that in such an untoward incident, there would always be a qualified Pilot to take over command of the aircraft and proceed with the next safe course of action.

As the training progressed, and if the trainee's performance was above average, and deemed safe, the carriage of the third pilot would not be necessary beyond this stage of training, based on the recommendation of the earlier trainer (TRI/TRE) in accordance with the training policy.

In such a case, a trainee pilot under IOE would not need a third pilot to accompany the flight, even though he was effectively still in the training phase. This was the case on the day of the eventful flight.

On the B777 a pilot under training normally would require to operate a certain number of minimum sectors before he could be certified to be fully functional as a line operational pilot (end-of-training). Depending on the previous aircraft flown, the minimum and maximum number of required training sectors were, as follows:

- Last aircraft flown B737: Minimum 10 sectors, Maximum 14 sectors; and
- Last aircraft flown A330: Minimum 8 sectors, Maximum 14 sectors.

xiii) Multi-crew Operation MH370

During the day of the eventful flight, the FO was on his last training flight before he was due for a check flight on his next flight duty assignment. Record shows that he was assigned to be the flying pilot during that first leg from Kuala Lumpur to Beijing. The airline encouraged Captain to allow First Officer a fair share of flying and handling of the aircraft. Under normal practice, if the duty pattern involves more than 1 sectors, it is quite common that the additional sector will be flown by the First Officer. The decision of who to carry out the take-off and landing was solely at the discretion of the Captain. The assignment of duty regarding who was going to be the flying pilot for the first flight out normally decided during the pre-flight briefing at the despatch office.

If the decision was made that the First Officer was going to be the Pilot Flying, the MAS Flight Operations policy required that the Captain would start and taxi the aircraft up to the take-off point on the runway, after which control of the aircraft would be handed over to the co-pilot to perform the take-off and eventually the landing at the destination. Up to the take-off position at the beginning of the runway, radio communications with the ATC would be the responsibility of the co-pilot. It was a MAS' written procedure during this phase of the flight that the throttle would be handled by the Captain as PIC, a policy to ease and expedite the rejected take-off manoeuvre if so required. The First Officer would control the rudder and control column as the pilot flying.

As soon as control was handed over to the co-pilot at the take-off point, the ATC communication became the responsibility of the Captain. Evidence from the KL ATSC's voice recording indicated clearly (in interviews with the Captain's colleagues, friends and son), that the voice recorded was that of the Captain after the aircraft took off.

xiv) Safety and Emergency Procedures

Proficiency in Safety and Emergency Procedures (SEP) was also a part of the mandatory training requirement which was conducted every 12 months. It was based on the Aircraft Type that the pilot was rated on. This recurrent training required a minimum of 3 days which covered all aspects of emergencies including medical and first aid knowledge. This section of Training fell under the purview of Flight Safety and Human Factor.

(1) Operation Control Centre

The Operation Control Centre (OCC) was where the briefing of flight crew and cabin crew took place. A team of Licensed Aircraft Despatchers were stationed in this Department.

Besides the crew formalities required prior to departure, the flight crew would be working in tandem with the assigned despatcher to review all documentations related to the assigned flight which influenced the decision on the finalised routing and fuel ordered by the Captain of the flight.

(2) Flight-Following System

In MAS, the FFS was an integrated approach which enabled flight operations Controllers to easily monitor the status of flights and gain a better view of impending operational problems, and making the process of resolving them much more efficient. A 24-hour OCC maintained operational control of all fleets in MAS by providing support for the pilots before and during flights. The FFS played the foundational role in OCC. The system is a product from Sabre and utilises position input to update the aircraft's geographical position. Position updates come from two sources namely:

- ASDI (Aircraft Situation Display Information) sourced from the FAA for aircraft flying in the United States, and

- ACARS update from individual Company aircraft flying anywhere in the world.

The information was available on a monitor mounted in the ODC and was also available on all Despatchers' positions via selections to be displayed on individual monitors.

- Projected flight plan against hazardous weather and published prohibited or restricted areas en-route;
- Actual flight data; and
- Pertinent data related to the flight, and allows direct communications with aircraft via satellite phone or ACARS communications.

xv) Technical and Development

Technical data and aircraft performance were under the control of the Operations Engineering Department. This Department worked closely with the Technical Services Department of the Engineering Division and Aircraft Manufacturers on Performance Engineering matters. The Technical and Development Department participated in the evaluation of new Aircraft Type and Aircraft Equipment.

xvi) Fuel Policy

The fuel policy defined in the *MAS Operations Manual A (Part 8.1.7)* met the minimum required for aircraft despatch. A Captain has the privilege of carrying extra fuel if he feels that there is justification to do so, based on expected weather forecast enroute and at the destination. Extra Fuel carriage can also be due to aircraft performance penalty as required by MEL or specific ATC requirement at some destination airports.

xvii) Flight Plan Routing

The Company's policy required the despatcher to evaluate the flight routing for the best economy routes to Beijing based on the OCC Flight Management System. As there was no known enroute weather forecast that could pose a threat for MH370, the usual standard routing was chosen. This was normally done by the computer system to give the despatcher the recommended routing unless otherwise modified.

xviii) Hijack and Sabotage Security Procedures

The Hijack and Sabotage Security Procedures and Guidelines in MAS's SEP Manual (Part 4.3) were recommended by the world's aviation security authorities based on in-depth studies of actual hijack and sabotage incidents. These authorities included ICAO Annex 17, IATA, TSA, FAA, Malaysia Airlines Security Programme and the Aviation Offences Act 1984 (Act 307).

The procedures stipulated that security precautions against both hijack and sabotage cannot be maintained at maximum level at all times without disrupting operational functions and public goodwill.

b) In-flight Services

i) Cabin Crew Training

Cabin crew were required to be present on public transport flights to perform duties in the interest of passengers' safety. They must be well-informed about safety and Policies of the Company. Each cabin crew member shall:

- Be well-prepared and fit for the flight;
- Ensure adherence of "Fasten Seat Belt" and "No Smoking" signs;
- Ensure the comfort and safety of all passengers; and

- Ensure passengers safely escape in an emergency evacuation.

A cabin crew member is a person employed to facilitate the safety of passengers whose duties are detailed by the Company or the aircraft Commander. Cabin crew will not act as a member of the flight crew.

At the point of recruitment, the candidate would have to undergo through a thorough interview and medical check-up. Once selected, a comprehensive training of safety and service procedures would be provided by the airline for the duration of 3 months and he/she would graduate and leave the academy as a qualified cabin crew assigned to the selected fleet that he/she was trained for.

MAS had the policy of fleet grouping for cabin crew in the following order:

- Narrow Body - B737
- Wide Body - A330, B777 & B747/A380

Upon graduation, the cabin crew would be given a flight duty roster on a monthly basis. The roster was managed by the Crew Planning & Deployment Section.

Initially, a cabin crew was required to operate the domestic and the regional flights known as the Narrow Body Fleet for a minimum of 2 years. With sufficient experience gained on the narrow body fleet he/she might be eligible for promotion to the wide-body fleets. These new wide-body may include long-haul flights to international destinations. The selection of cabin crew for promotion normally depends on merit, track record and seniority.

A cabin crew would be provided with proper training on Safety and First Aid. He/she would be trained to handle:

- Safety and emergency evacuation
- Disruptive/Difficult passengers
- Medical emergency (Provide First Aid)

On a yearly basis, the cabin crew was required to go through a safety recurrent training on their Safety Emergency Procedures (SEP) at the academy in order to keep his/her licence and training validated by certified instructors. It was mandatory for the crew to achieve the required minimum safety and emergency procedures and knowledge which were assessed through examinations. This recurrent training included first aid training and examination, to get the certificate renewed. There were also “Safety Awareness Programme” and “Crew Resources Management” classes that were compulsory for the cabin crew to attend every 2 years. These two programmes were basically similar, and they were incorporated within the 3 days of training.

The cabin crew would be issued with a Safety Card endorsed by the Safety and Human Factors Department of MAS as well as a Crew Performance Card issued by the Cabin Crew Line Operation and Performance Department. The crew would be expected to carry these two documents at all times for flight duty.

Excellent service awards won by the Company’s cabin staff for several years stood as a testimony for the quality of the training and the service standards acquired. MAS’ reputation had attracted foreign established top-rated airlines for secondment of cabin crew.

ii) Crew Performance Appraisal

The Crew Performance Appraisal (CPA) was an established process in the organisation, monitoring crew performance and standards including safety knowledge. To maintain and achieve a high standard of service and safety, each and every cabin crew was required to have a CPA which was done twice a year. The assessment was carried out by the crew in charge on board during the flight.

Refer *Table 1.17D* (below) on Rating Score.

The cabin crew would be checked on aspects such as safety and service procedure, product knowledge, Customs, Immigration and Quarantine, station documents, grooming and leadership skills. The crew in charge would conduct the checking on the crew by Questions & Answers (Q & A) and how the individual performed as part of the operational crew member in his/her assigned capacity.

Ratings	Category	Range of Score
5	Amongst the Best	98% and above
4	Highly Effective	93%-97.90%
3	Fully Productive	87%-92.90%
2	Needs Improvement	80%-86.90%
1	Unacceptable	<80%

Table 1.17D - Crew Rating Score

iii) In-flight Operation

On board a Boeing 777-200ER aircraft the standard operating cabin crew of 11 was required. The normal cabin crew complement for the Boeing 777-200ER aircraft was as follows:

- 1 In-flight Supervisor
- 2 Chief Steward/Chief Stewardess
- 2 Leading Steward/Leading Stewardess
- 6 Flight Steward/Flight Stewardess

The 777-200ER fleet had a two-class cabin configuration, namely Golden Class Club (GCC) and Economy Class (EY). Four cabin crew would be designated to work in GCC and six in EY.

The In-flight Supervisor would be in charge of the whole cabin. Two Chief Stewards/Chief Stewardesses looked after the GCC assisted by two cabin crew. Six cabin crew were designated to work in EY class. The EY class was divided into two sections and each section was looked after by one Leading Steward/Leading Stewardess and assisted by two cabin crew.

The In-flight Supervisor was the person responsible to manage the cabin safety and report to the Commander of the aircraft.

He or she shall:

- have the overall responsibility to the aircraft commander for the conduct, coordination and performance of the cabin operations and the safety duties;
- verify that all the cabin crew members are fit for flight and with all relevant documents valid for flight duty; and
- coordinate and organise the functions and tasks of all cabin crew members:
    - Execute cabin crew briefing;
    - Nominate positions and working areas;
    - Nominate in-flight service duties;
    - Checking of emergency equipment, pre-flight safety briefing and reporting matters concerning safety (irregularities and malfunctions) to the Commander;
    - Debriefing the cabin crew members when required;
    - Ensuring efficient communication with crew members and ground personnel; and
    - Ensuring contact with the cockpit on a regular basis.

As per Civil Aviation Regulations 1996 the minimum requirement of the operating cabin crew for B777-200ER fleet is 8 based on the number of exit doors available on the aircraft.

Notwithstanding the above, many other airlines carry additional cabin crew above the minimum required in the interest of customer services.

iv) Flight and Duty Time Limitations Scheme for Cabin Crew

The prime objective of a flight time limitations scheme is to ensure that crew members are adequately rested at the beginning of each flying duty period, and whilst flying, be sufficiently free from fatigue so that they could operate to a satisfactory level of efficiency and safety in all normal and abnormal situations.

The maximum duty hours for cabin crew should not exceed:

- 60 hours in 7 consecutive days;
- 105 hours in any 14 consecutive days; and
- 210 hours in any 28 consecutive days.

Cabin crew would be notified in advance of a flying duty period so that sufficient and uninterrupted pre-flight rest can be assured in preparation for the flight. When away from base, opportunities and facilities for adequate pre-flight rest would be provided by the Company with suitable accommodation.

The minimum rest period which must be taken before undertaking a flying duty period shall be:

- At least as long as the preceding duty period, or
- 12 hours, whichever is the greater.

The minimum rest period would be the highest of pre-flight or post-flight rest. It was not cumulative of both rests.

The minimum rest period which must be provided before undertaking a flight, at home base would be:

Flight	Rest Period
Pre-flight	40 hours (inclusive 2-local nights)
Post-flight	72 hours (inclusive 3-local nights)

The minimum rest period which must be provided after performing a flight, out of base would be:

Flight	Rest Period
Post-flight	24 hours

MAS Employee Union (MASEU) was the recognised union certified by MAS to represent the cabin crew. Flight Time Limitation and working conditions were governed by the Collective Agreement (CA) signed between the union and MAS, in compliance with CAR or whichever was more limiting.

v) Safety Report

(1) Accident/Incident/Hazard Reports Form

MAS managed an in-house reporting system to identify many of these accidents/incidents/hazards by collecting and then analysing hazard and incident reports to audit incidents encountered during flight. The Incident reporting system was one of the most effective tools for pro-active hazard identification. Cabin crew were required to fill up this form and to submit it at the end of the flight within 24 hours.

(2) Confidential Human Factors Incident Reporting Programme

Confidential Human Factors Incident Reporting Programme (CHIRPs) applicable for the flight crew, cabin crew and engineering personnel only. It was a non-disclosure type of document where one could use and submit to the Company to report any complaints and issues. CHIRPs could only be used for human factor and safety issues, errors and unsafe practices and where some actions might potentially infringe regulatory practises. It was not to be used for mandatory incidents reporting, personality conflicts, industrial issues and employment problems. It would be reviewed by the members of the CHIRPs staff and action would be taken accordingly.

All these reports were managed by the Corporate Safety Oversight and Human Factors Department.

SECTION 1 – FACTUAL INFORMATION

1.18 ADDITIONAL INFORMATION

1.18.1 Provision of Air Traffic Services and Areas of Responsibilities

1) Introduction

For the provision of Air Traffic Services (ATS), the Kuala Lumpur FIR is divided into seven Sectors, namely Sector 1, Sector 2, Sector 3, Sector 4, Sector 5, Sector 6 and Sector 7.

Each Sector has a specified area of responsibility. Sectors 1 to 5 are manned by Sector Planning and Radar Controller jointly responsible for the safe, efficient and orderly provision of air traffic control service, flight information service and alerting service in their Sectors. Each Sector has an Assistant Flight Data (AFD) Controller.

Sector 6 is manned by a Radar Controller and supported by the Sector 1 Planning Controller and Sector 1 AFD Controller. Sector 7 is manned by a Radar Controller and supported by the Sector 2 Planning Controller and Sector 2 AFD Controller.

a) Responsibilities of Sector Radar Controller:

- Handle all radiotelephony functions;
- When necessary, coordinate to effect transfer of radar identity and control;
- Monitor the Sector Inbound List (SIL) to ensure appropriate action for orderly acceptance, control and transfer of aircraft; and
- Comply with instructions issued by FLOW control.

b) Responsibilities of Sector Planning Controller:

- Plan and coordinate as necessary for the management of all flights that will operate in their sectors; and
- Ensure that the information on the electronic flight strips (EFS) is updated.

The Radar and Planning Controllers will make available to each other information that is essential to enable them to carry out their responsibilities, e.g. change in cruising level/altitude or revision to transfer of control point estimates.

c) Responsibilities of Controllers at AFD Position:

- Assist the Planning Controller by ensuring that information displayed on the EFS is kept updated in a timely manner;
- Ensure that essential information found on the EFS is also available on the paper strips;
- Display the paper strips on the display board in the correct manner;
- Make paper strips available to the EXE Controller if requested;
- Wrap up all used strips, and place them at a common place for collection; and
- Clear wrong ADP Message Queues as follows:
  - AFD Sector 2 - wrong AFTN Message Queue
  - AFD Sector 5 - wrong METEO and AIS Message Queue
  - AFD Sectors 1 & 4 - wrong FDP Message Queue

2) Sector 3 Area of Responsibility

a) Sector 3 is responsible for the provision of air traffic services in controlled airspace and outside controlled airspace above FL145 within:

That airspace from VKL to PIBOS then to 033658N 1022253E then to 040051N 1034109E at the border of Peninsular Malaysia/Singapore International Boundary, thence southwards along the FIR boundary to 012652N 1034540E thence northwards to 021958N 1034235E (10 nm west of VMR) thence westwards to DAMAL thence northwards along the airway R325 to SAROX (but *excluding ATS Route R325) thence along the airway G334 to VKL but excluding the Kuantan TMA.*

b) Sector 3 is also responsible for the provision of FIS and Alerting Service in the South China Sea Corridor (SCSC). The lateral and vertical limits of the SCSC (Refer *Table 1.18A* [below]) are as follows:

Laterals Limits	Vertical Limits
From 023600N 1044500E to 020000N1070000E and along 020000N till the Singapore/Kota Kinabalu FIR Boundary, thence along this Boundary to 060000N 1132000E, thence along 060000N till the Singapore/Kuala Lumpur FIR Boundary, thence along this Boundary to 023600N 1044500E	West of 105E FL150 GND/SL East of 105E FL200 GND/SL

Table 1.18A - Lateral and Vertical Limits of South China Sea Corridor

c) Sector 3 encompasses the following ATS routes or route segments *(Table 1.18B* [below]*):*

Routes	Segments	Routes	Segments
A224	VMR - VJR	N884	VMR – LENDA
B338	VTK - VMR	N891	PU – MANIM
B469	VPK - PU	N892	KIBOL - VMR
G334	VKL - UKASA - VPT - KIBOL	R221	VMR - VPT
G582	Sector 1 boundary - VPK	R325	MATSU - SAROX (FL280 & below)
G584	VKL – VPK	W533	VKL - VKN - VKE
L629	VPK - BUVAL	W540	VPK - A/VKE (FL235 & below)
L635	VPK - DOVOL	Y331	PIBOS - TAXUL
L642	VMR - EGOLO	Y332	TAXUL - PADLI
M751	VPK - A/VKE (FL240 & above)	Y333	PADLI - BUVAL
M758	VPK - ISDEL	Y334	PADLI - DOVOL
M761	VPK - KETOD	Y335	PADLI - IDSEL
M763	VPK - TAXUL	Y336	ISTAN - PADLI - KETOD
M771	VMR - RAXIM	-	-

Table 1.18B - ATS routes or route segments of Sector 3

Note*:*

SAROX is not a waypoint on R325. It is a waypoint on G334 that intersects R325. It is used here for ease of reference.

d) Delegation of Airspace and Communication Watch

i) Delegation of Airspace from Kuala Lumpur ACC (Sector 3) to Singapore ACC

The contiguous airspace Areas A, C, E and H along eastern Johor/South China Sea and responsibility for provision of air traffic services in these areas remains delegated to Singapore.

ii) Communication Watch

To ease air traffic management, communications watch shall be maintained by Singapore HF, Lumpur Sector 3 and Lumpur HF within South China Sea Corridor (AIP Malaysia ENR 2.1-13 [below]*).*

AREAS WITHIN THE SINGAPORE FIR FOR WHICH LUMPUR ACC IS RESPONSIBLE FOR PROVIDING ATS.					
SOUTH CHINA SEA CORRIDOR Fm 023600N 1044500E to 020000N 1070000E and along 020000N till the Singapore / Kota Kinabalu FIR BDRY - thence along this BDRY to 060000N 1130000E, thence along 060000N till the Singapore/Kuala Lumpur FIR BDRY - thence along this BDRY to 023600N 1044500E.	W of 105E FL 150 GND / SEA E of 105E FL 200 GND / SEA	Lumpur ACC	Lumpur Control Lumpur Radio English H24	132.6 MHz HF 5655 KHz 8942 KHZ 11396 KHz	Lumpur ACC shall be responsible for the provision of air traffic services to flights operating within the South China Sea Corridor.

Extract from Malaysia AIP ENR 2.1-13

iii) Singapore will pass to Sector 3 Estimate for flights bound for the Natuna and Matak Islands. Sector 3 in turn, shall notify Aeronautical Mobile Service (AMS) High Frequency (HF) who shall provide additional communications watch in order to discharge its Flight Information Service (FIS)/Alerting Service functions.

3) Sector 5 Area of Responsibility

a) Sector 5 is responsible for the provision of air traffic services in controlled airspace and outside controlled airspace above FL145 within:

That airspace from VKL to PIBOS then to 033658N 1022253E then to 040051N 1034109E at the border of Peninsular Malaysia/Singapore International Boundary, thence northwards along the FIR boundary, thence westwards along the Peninsular Malaysia/Thailand International Boundary to 054342N 1010038E thence southwards to 044021N 1012704E, then to VKL but excluding the Kota Bharu TMA/Terengganu and Kerteh CTRs. Sectors 5 encompasses the following ATS routes or route segments *(Table 1.18C* [below]*)*:

Routes	Segments
A334	PASVA – VKB
B219	Butterwort TMA Boundary East – VKB
B463	KADAX – VKB
G466	VKL – VKB
M644	VKB – ABTOK
M751	A/VKE – VKB – GOLUD (FL240 and above)
M765	VKB – VENLI – IGARI
R208	VKL – GUNBO – VKR – IKUKO – IGARI
R325	ANSOM – MATSU (FL 280 and below)
W540	A/VKE – VKB (FL235 and below)

Table 1.18C - ATS routes or route segments

b) Delegation of Airspace

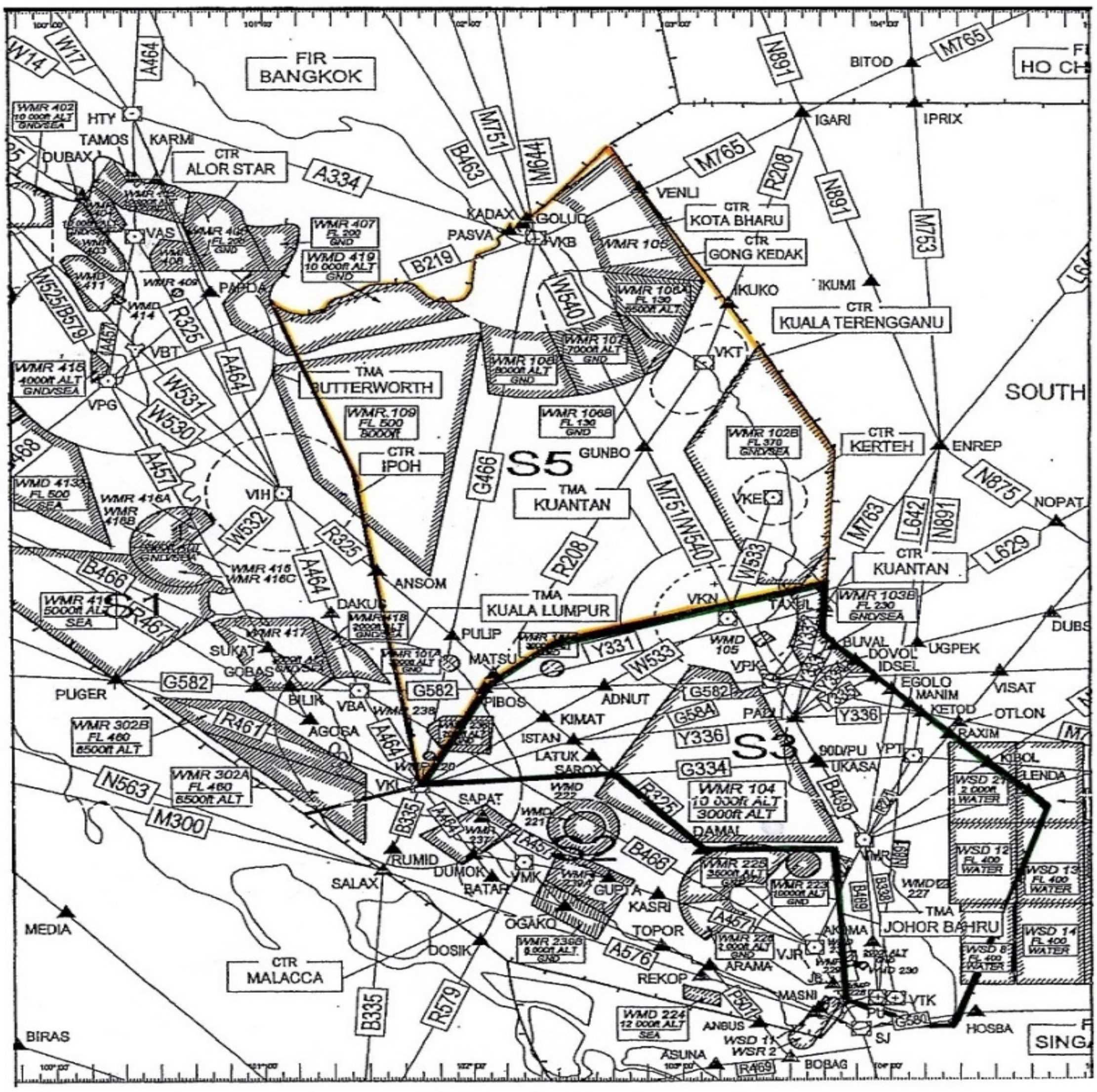
i) Delegation of Airspace from Singapore ACC to Kuala Lumpur ACC (Sector 5)

RNAV route M765 between VENLI and IGARI has been delegated by Singapore ACC. Lumpur Sector 5 shall provide air traffic services and carry out coordination with Ho Chi Minh ACC.

ii) Route segment between IKUKO and IGARI on ATS R208 is released by Singapore ACC subject to daily coordination between Singapore ACC and Kuala Lumpur ACC.

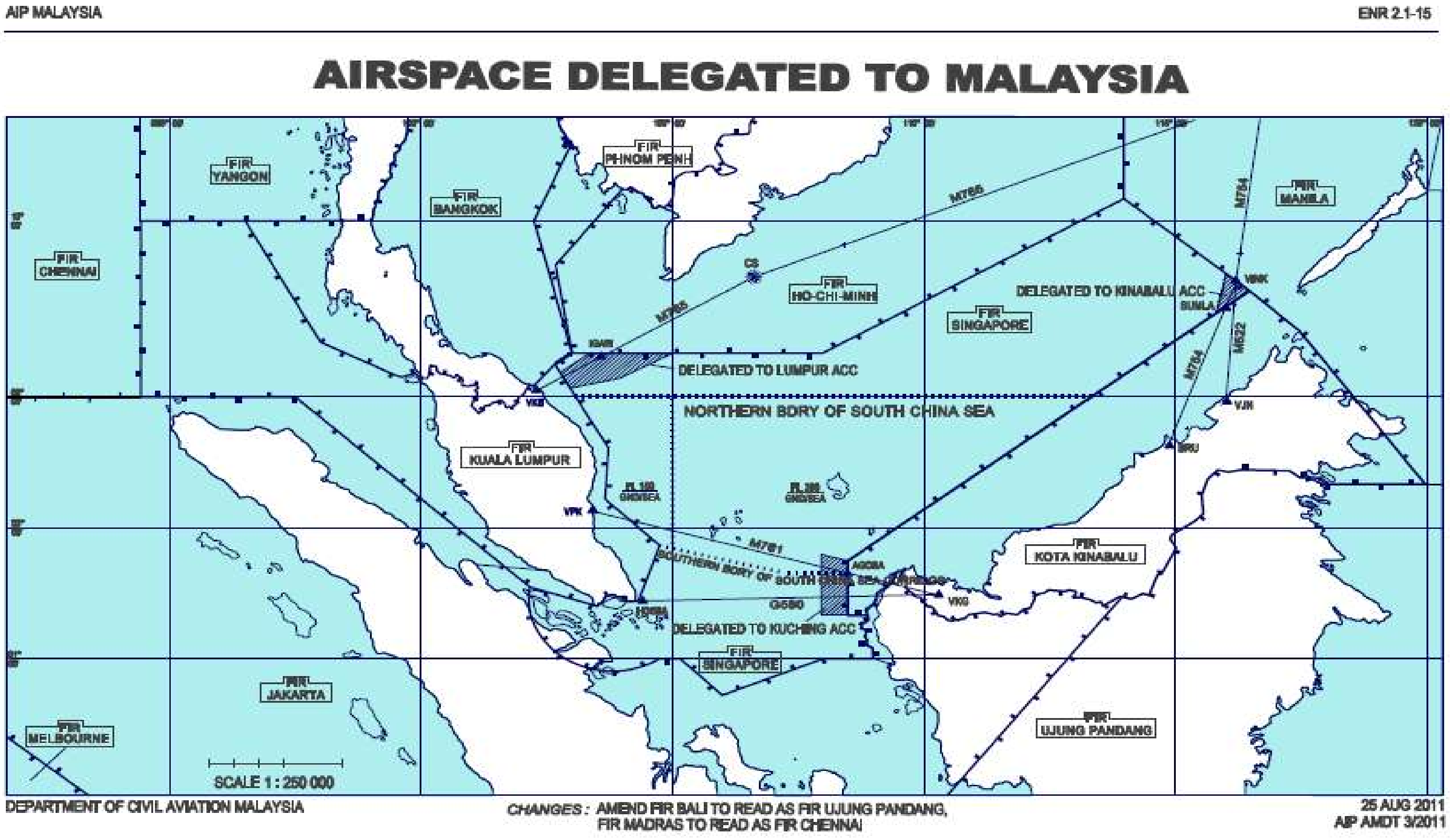
iii) Communication Watch

To ease air traffic management, communication watch is maintained by Lumpur Sector 5 and Lumpur HF between IKUMI and IGARI along N89. Refer *Figure 1.18A - Sector 3 and 5 Area of Responsibilities* (below).



Source: DCA Malaysia

Figure 1.18A - Sector 3 and 5 Area of Responsibilities



Source: DCA Malaysia

Figure 1.18B - Airspace Delegated to Malaysia by Singapore

4) Air Traffic Services Operations

a) The disappearance of MH370 occurred in the Singapore FIR where the airspace is delegated to KL ACC. The portion of airspace delegated is RNAV route M765 between VENLI[13] and IGARI[14], and the portion released is ATS route R208 between IKUKO[15] and IGARI. (References: Malaysia Aeronautical Information Publication (AIP) ENR 2.1-15 (*Figure 1.18B* [below]), ENR 3.1-10 and ENR 3.3-5 and Manual of Air Traffic Services [MATS] Vol. 2 page 2-2-10 paragraphs 2.4.3.1 & 2.4.3.2).

b) KL ACC is responsible for the provision of Air Traffic Control Service, Flight Information Service and Alerting Service to all aircraft within Kuala Lumpur FIR and the "released airspace" on ATS route R208 and the "delegated airspace" on RNAV route M765 (*Figure 1.18B* [above]).

c) MATS part 9, page 9-6-5 para 6.7.2 states that:

> "*If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegated to the Kuala Lumpur and Kota Kinabalu ATSCs and, the position of the aircraft is in doubt, the responsibility for coordinating such service shall normally rest with the ATSC of the respective FIRs:*
>
> *a) Within which the aircraft was flying at the time of last radio contact;*
>
> *b) That the aircraft was about to enter when last radio contact was established at or close to the boundary of the two FIRs.*

d) Operational Letter of Agreement for the Provision of Search and Rescue Services between the Department of Civil Aviation Malaysia and the Department of Civil Aviation Singapore dated August 1984 page 6 para. 7.1 states that:

[13] Coordinates VENLI: 062846N 1024900E
[14] Coordinates IGARI: 065612N 1033506E
[15] Coordinates IKUKO: 054512N 1031324E

"In the event of an aircraft emergency occurring within

the South China Sea Corridor (SCSC), the KL ATSC shall be responsible to take initial alerting action whilst the Singapore RCC shall be responsible for subsequent coordination of all SAR efforts. While the responsibility for the provision of SAR service within the SCSC rests with Singapore RCC, the Singapore RCC may as provided for in paragraph 3.2.2 delegate responsibility for the overall control of the SAR mission to Kuala Lumpur RCC or Kota Kinabalu RCC, whichever is deemed appropriate"

Para. 3.2.2, page 3 of the same agreement, para. (d) above states that:

"*When a transfer of responsibility for the overall SAR co-ordination is to take place, either from subsequent establishment of an aircraft's position or movement, or because an RCC other than the one initiating the action is more favourably placed to assume control of the mission by reason of better communication, proximity to the search area, more readily available facilities or any other reasons, the following procedures shall be adopted:*

i. direct discussions, wherever possible, shall take place between the Search and Rescue Mission Co-ordinators (SMCs) concerned to determine the course of action.

ii. if it decided that a transfer of responsibility is appropriate for the whole mission or part thereof, full details of the SAR mission shall be exchanged.

iii. the initiating RCC shall continue to retain responsibility until the accepting RCC formally assumes control for the mission.

5) KL ATSC Duty Shift System for Air Traffic Controllers

a) The duty shift system *(Table 1.18D* [below]*)* on 07 March 2014 for Air Traffic Controllers was as follows:

Sectors 1, 2, 3, 4 and 5 were manned by a Radar Controller, a Planning Controller and an Assistant Flight Data Controller in each Sector from 1100-1600 UTC [1900-2400 MYT]. Sector

6 was manned by a Radar Controller and Sector 7 was not manned.

Day	Shift	Period
1	Afternoon	• 0500 UTC [1300 MYT] - 1100 UTC [1900 MYT]
2	Morning & Night	• 2300 UTC [0700 MYT] - 0500 UTC [1300 MYT] and • 1100 UTC [1900 MYT] - 1600 UTC [2400 MYT]
3	Midnight shift	• 1600 UTC [0000 MYT] - 2300 UTC [0700 MYT]
4	Off duty	

Table 1.18D - Duty Shift System for Air Traffic Controllers

b) From 1600 UTC [0000 MYT] until 2200 UTC [0600 MYT], the number of Controllers in the KL ATSC were scaled down by or to half to enable the Controllers to take a rostered break - the first half from 1600 UTC [0000 MYT] to 1900 UTC [0300 MYT] and the second half from 1900 UTC [0300 MYT] to 2200 UTC [0600 MYT], as follows:

- Sector 1, Sector 2 and Sector 4 each were manned by a Radar Controller with an AFD Controller.
- Sector 3 and Sector 5 were combined and operating from a Controller working position with a Radar Controller and an AFD Controller.
- The area of responsibility would be that of Sector 3 and Sector 5. Between 1600 UTC [0000 MYT] and 2200 UTC [0200 MYT], Sectors 3 and 5 Assistant Flight Data Controller carried out the duty of Planning Controller.

c) The last radio transmission between KL ACC and MH370 took place at 1719:30 UTC [0119:30 MYT]. A contact should have occurred at around 1722 UTC [0122 MYT] at waypoint IGARI.

Reference is made to Malaysia AIP ENR 6, En-route Charts - IGARI has been designated as a compulsory reporting point, and MATS page 8-2-6, Part 8 Surveillance para 2.4.1 - Controllers may instruct a radar identified aircraft to omit making compulsory position reports unless:

- *the position report is required for control purposes.*

There was no instruction by the KL ACC Controller to MH370 to omit making compulsory position report as stated in MATS.

KL ACC should have declared the Distress Phase[16] at 1827 UTC [0227 MYT] and the transmission of the *DETRESFA*[17] message, as KL ACC was the ATS unit last in contact with MH370 at 1719:30 UTC [0119:30 MYT] when MH370 acknowledged the transfer of control by KL ACC at 1719:26 UTC [0119:26 MYT].

MH370 did not contact Ho Chi Minh ACC on radio frequency 120.9 MHz. and Ho Chi Minh ACC was not able to establish two-way communication with MH370.

<u>Reference</u>

Manual of Air Traffic Services, Part 9 - Emergencies, page 9-6-5, para. 6.7.2 dated 15/3/2009 No.1 states:

> *If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegate to the Kuala Lumpur and Kota Kinabalu ATSCs and the position of the aircraft is in doubt, the responsibility for co-ordinating such service shall normally rest with the ATSC of the respective FIRs:*
>
> - *within which the aircraft was flying at the time of last air-ground radio contact;*
> - *that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;*
> - *within which the aircraft's intermediate stop or final destination point is located:*
>
>   *1) if the aircraft was not equipped with suitable two-way radio communication, or*

[16] *Distress Phase - A situation wherein there is a reasonable certainty that an aircraft and its occupants are threatened by grave and imminent danger and require immediate assistance.*

[17] *DETRESFA - The code for a Distress Phase*

2) was not under obligations to transmit position reports.

and

ICAO Doc 4444 ATM/501 Procedures for Air Navigation - Air Traffic Management (PANS-ATM), page 9-6, para 9.2.2.2, dated 22/11/07 states:

When alerting services is required in respect of a flight operated through more than one FIR or control area, and when the position of the aircraft is in doubt, responsibility for coordinating such service shall rest with the ATS unit of the FIR or control area:

a) within which the aircraft was flying at the time of last air-ground radio contact;

b) that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;

c) within which the aircraft's intermediate stop or final destination point is located:

1) if the aircraft was not equipped with suitable two-way radio communication, or

2) was not under obligations to transmit position reports.

The Team noted that MH370 was operating in the airspace delegated to KL ACC and the last air-ground radio contact was with KL ACC. MH370 did not contact Ho Chi Minh ACC and Ho Chi Minh ACC was unable to establish radio communication with MH370.

Hence KL ACC shall be responsible for the provision of alerting service for MH370.

At 2232 UTC [0632 MYT] KL ARCC transmitted the first *DETRESFA* message. A total of 4 hours and 05 minutes had passed from the time the Distress Phase should have been declared.

d) As the 'custodian' of the airspace, the KL ACC transferred MH370 to HCM ACC 3 minutes before the estimated time of arrival over the Transfer of Control Point[18] (TCP).

The estimate[19] of the aircraft for IGARI which was 1722 UTC [0122 MYT] had been passed to, by KL ACC, and duly acknowledged by HCM ACC, as stipulated in the Operational Letter of Agreement between DCA Malaysia and Viet Nam Air Traffic Management.

e) Page 11 of *Appendix 1.1A - Establishment of Communication* in the Operational Letter of Agreement between DCA Malaysia and Viet Nam Air Traffic Management stipulates that:

"The accepting unit shall notify the transferring unit if two-way communication is not established within five (5) minutes of the estimated time over the TCP".

At 1739:03 UTC [0139:03 MYT] HCM ACC queried KL ACC for news on MH370.

After MH370 was transferred to HCM ACC, the time of transfer was not recorded manually on the paper Flight Progress Strip as stipulated in MATS Part 2-Gen Section 11 FLIGHT PROGRESS STRIPS.

Manual of Air Traffic Services Part 9, Table 9-2.2 Overdue Action - Radio Equipped Aircraft preliminary action stipulates that:

"*When an aircraft fails to make a position report when it is expected, commence actions not later than the ETA*[20] *for the reporting point plus 3 minutes"* and

a) The following actions shall be taken:

---

[18] *Transfer of Control Point - A defined point located along the flight path of an aircraft, at which the responsibility for providing air traffic control service to the aircraft is transferred from one control unit or control position to the next.*

[19] *Estimate - The time at which it is estimated that an aircraft will be over a position or over the destination.*

[20] *ETA* - Estimated time of Arrival.

(1) request information from other ATS units and likely aerodromes;

(2) notify the RCC that the Uncertainty Phase[21] *exists;*

(3) ensure that RQS[22] *message is sent.*

b) Full Overdue Action: not later than 30 minutes after the declaration of the Uncertainty Phase:

i. notify the RCC that the Alert Phase[23] *exists.*

ii. notify the RCC that Distress Phase exists if:

-*1 hour has elapsed beyond the last ETA for the destination; or*

- *the fuel is considered exhausted; or*

- *1 hour has elapsed since the declaration of the Uncertainty Phase*.

MATS Part 9 para 6.2.3 stipulates that:

"*If Controllers have reason to believe that an aircraft is lost, overdue or experiencing communication failure, they shall:*

a) inform appropriate radar units (civil and military) of the circumstances,

b) request the units to watch out for emergency SSR code display or the triangular radio failure pattern, and

c) notify these units when their services are no longer required."

---

21 *Uncertainty phase - A situation wherein doubt exists as to the safety of an aircraft or a marine vessel, and the Persons on board.*

22 *RQS - Request Supplementary Flight Plan.*

23 *Alert phase - A situation wherein apprehension exists as to the safety of an aircraft or marine vessel and of the persons on board.*

At 1741:23 UTC [0141:23 MYT] KL ACC Sector (3 & 5) Controller made a call on the radio frequency 132.5 MHz to MH370 but there was no response from the aircraft.

Event that followed was at the time of 1804:39 UTC [0204:39 MYT] when KL ACC Radar Controller informed HCM ACC:

> *"…reference to the Company Malaysian Airlines the aircraft is still flying, is over somewhere over Cambodia*".

Thirty-one minutes later, at 1835:52 UTC [0235:52 MYT] MAS Operations Centre (MOC) informed the position of the aircraft was at latitude N14.9 0000 and longitude E109 15500 which was somewhere east of Vietnam. This information was relayed to HCM ACC. At 1930 UTC [0330 MYT] MOC called in and spoke to the Radar Controller, "…*admitting that the 'flight tracker'*[24] *is based on projection and could not be relied for actual positioning or search."* (*Watch Supervisor Logbook's entry*).

6) Chronology of Activities after Notification by HCM ACC

The paragraphs (*Table 1.18E* [below]) describe the chronology of activities after notification by HCM ACC leading to the initiation of the Search and Rescue operations (SAR) and deployment of resources for the MH370 search.

Refer Radiotelephony Transcripts - *Appendices 1.18A to 1.18G - Air-Ground Communications.*

[24] *MAS Operations Centre used the name 'Flight Explor*er'.

a) Chronology of ATC Activities after Notification by HCM ACC

No.	Time	Activities
1.	1739:03 UTC [0139:03 MYT]	Ho Chi Minh ACC first enquired about MH370 and informed KL ACC that verbal contact was not established with MH370 and the radar target was last seen at BITOD.
2.	1741:22 UTC [0141:22 MYT]	Ho Chi Minh enquired for information on MH370 and KL ACC informed HCM ACC that after waypoint IGARI, MH370 did not return to Lumpur Radar frequency.
3.	1741:23 UTC [0141:23 MYT]	KL ACC Radar Controller made a "blind transmission" to MH370.
4.	1746:47 UTC [0146:47 MYT]	HCM ACC queried about MH370 again, stating that radar contact was established over IGARI but there was no verbal contact. HCM ACC advised that the observed radar blip disappeared at waypoint BITOD. HCM ACC stated that efforts to establish communication were made by calling MH370 many times for more than twenty (20) minutes.
5.	1750:28 UTC [0150:28 MYT]	KL ACC queried HCM ACC if there had been any contact with MH370, HCM ACC's reply was "negative".
6.	1757:49 UTC [0157:49 MYT]	HCM ACC informed KL ACC that there was officially no contact with MH370 until this time. Attempts on many frequencies and through other aircraft in the vicinity received no response from MH370.
7.	1803:48 UTC [0203:48 MYT]	KL ACC queried HCM ACC on the status of MH370, HCM ACC confirmed there was no radar contact at this time and no verbal communication was established. KL ACC relayed the information received from Malaysia Airlines Operations that the aircraft was in the Cambodian airspace.
8.	1807:47 UTC [0207:47 MYT]	HCM ACC queried for confirmation that MH370 was in Phnom Penh FIR as Phnom Penh did not have any information on MH370. KL ACC indicated it would check further with the supervisor.

Table 1.18E – ATC Activities after Notification by HCM ACC

cont…

a) Chronology of ATC Activities after Notification by HCM ACC *(cont…)*

No.	Time	Activities
9.	1812:15 UTC [0212:15 MYT]	KL ACC informed HCM ACC that there was no update on the status of MH370.
10.	1815 UTC [0215 MYT]	(*No voice recording*). Extracted from the Watch Supervisor Log Book: KL ATSC Watch Supervisor queried Malaysia Airlines Operations who informed that MH370 was able to exchange signals with the Flight Explorer.
11.	1818:50 UTC [0218:50 MYT]	KL ACC queried if the flight plan routing of MH370 was supposed to enter Cambodian airspace. HCM ACC confirmed that the planned route was only through the Vietnamese airspace. HCM ACC had checked and Cambodia had advised that it had no information or contact with MH370. HCM ACC confirmed earlier information that radar contact was lost after BITOD and radio contact was never established. KL ACC queried if HCM ACC was taking Radio Failure action, but the query didn't seem to be understood by the personnel. HCM ACC suggested KL ACC to call Malaysia Airlines Operations and was advised that it had already been done.
12.	1833:59 UTC [0233:59 MYT]	KL ACC Radar Controller enquired with Malaysia Airlines Operations Centre about the communication status with MH370 but the personnel was unsure if the message went through successfully or not. Malaysia Airlines Operations Centre informed that the aircraft was still sending the movement message indicating it was somewhere in Vietnam and giving the last position as coordinates N14.90000 E109 15500 at time of 1833 UTC [0233 MYT].
13.	1834:56 UTC [0234:56 MYT]	HCM ACC queried about the status of MH370 and was informed that the Watch Supervisor was talking to the Company at this time.

Table 1.18E – ATC Activities after Notification by HCM ACC

cont…

a) Chronology of ATC Activities after Notification by HCM ACC (*cont*…)

No.	Time	Activities
14.	1837:34 UTC [0237:34 MYT]	KL ACC informed HCM ACC that MH370 was still flying and that the aircraft was continuing to send position reports to the airline, and relayed to HCM ACC the latitude and longitude as advised by Malaysian Airlines Operations.
15.	1853:48 UTC [0253:48 MYT]	MH386 which was enroute from KLIA to Shanghai and within HCM FIR was requested by HCM ACC to try to establish contact with MH370 on Lumpur Radar radio frequency. KL ACC then requested MH386 to try on emergency frequencies as well.
16.	1930 UTC [0330 MYT]	(*No voice recording*) Extract from Watch Supervisor's Log Book: MAS Operations Centre informed KL ACC that the flight tracker information was based on flight projection and was not reliable for aircraft positioning.
17.	1930:03 UTC [0330:03 MYT]	KL ACC queried if HCM ACC had checked with next FIR Hainan.
18.	1948:52 UTC [0348:52 MYT]	When KL ACC queried whether HCM ACC had checked with the Sanya FIR, HCM ACC informed KL ACC that there was no response until now. At 1956:13 UTC [0356:13 MYT] KL ACC queried Malaysia Airlines Operations for any latest information or contact with MH370.
19.	2025:22 UTC [0425:22 MYT]	HCM ACC Supervisor queried KL ACC on the last position that MH370 was in contact with KL ACC.
20.	2118:32 UTC [0518:32 MYT]	When HCM ACC queried for information on MH370, KL ACC also queried if any information had been received from Hong Kong or Beijing.
21.	2109:13 UTC [0509:13 MYT]	Singapore, on behalf of Hong Kong, enquired for information on MH370.

Table 1.18E – ATC Activities after Notification by HCM ACC

cont…

a) Chronology of ATC Activities after Notification by HCM ACC (*cont*…)

No.	Time	Activities
22.	2120:16 UTC [0520:16 MYT]	Capt. *xxxx [name redacted]* of MAS requested for information on MH370. He opined that based on known information, *"MH370 never left Malaysian airspace".*
23.	2130 UTC [0530 MYT]	Watch Supervisor activated the Kuala Lumpur Aeronautical Rescue Coordination Centre (ARCC).
24.	2141:20 UTC [0541:20 MYT]	HCM ACC queried for any updates.
25.	2214:13 UTC [0614:13 MYT]	KL ACC queried HCM ACC if SAR was activated.
26.	2232 UTC [0632 MYT]	KL ARCC issued a *DETRESFA* message (*Figure 1.18C* [below]).

Table 1.18E – ATC Activities after Notification by HCM ACC

b) *DETRESFA* Message of MH370

```
KLA637 072232
SS WMKKZQZX WMKKZRZX
072232 WMFCZQZX
(ALR-DESTRESFA/WMFCZQZX/MISSING
-FPL-MAS370-IS
-B772/H-SDFGHIJ3J5M1RWXY/LB1D1
-WMKK1635
-N0470F290 DCT PIBOS R208 IKUKO/M081F330 R208 IGARI M765
 BITOD/N0480F330 L637 TSN/N0480F350 W1 BMT W12 PCA G221
 BUNTA/N0480F370 A1 IKELA/N0480F370 P901 IDOSI/N0480F390 DCT CH
 DCT BEKOL/K0900S1160 A461 YIN/K0890S1130 A461 VYK
-ZBAA0534 ZBTJ ZBSJ
-PBN/A1B1C1D1L1O1S2 DOF/140307 REG/9MMRO EET/WSJC0032 VVTS0042
 ZJSA0210 VHHK0233 ZGZU0304 ZHWH0356 ZPE0450 SEL/QRCS
 RMK/ACASII EQUIPPED
-E/0710 P/TBN R/UVE S/M J/LF D/8 290 GREY A/WHITE WITH RED AND
 BLUE STRIPE C/TBN)
```

Source: DCA Malaysia

Figure 1.18C - DETRESFA Message

7) Activation of KL Aeronautical Rescue Coordination Centre

KL ARCC was activated at 2130 UTC [0530 MYT]. The *DETRES*FA message was disseminated via the AFTN at 2232 UTC [0632 MYT], 01 hour and 02 minutes later. No activity was recorded in the RCC Logbook between 2130 UTC [0530 MYT] and 2232 UTC [0632 MYT].

The Kuala Lumpur Aeronautical Rescue Co-ordination Centre, Standard Operating Procedure for Search and Rescue, page 11, para 3.1 stipulated:

"The search and Rescue Mission Co-ordinator (SMC) is the officer assigned to co-ordinate response to an actual or apparent distress situation.

In aeronautical search and rescue operations, the SMC is usually in the best position to assess the circumstances of a particular case, and to take whatever steps necessary to promote the safety of life and prevent further loss of property.

The SMC must use his/her best judgment in initiating and coordination operations to ensure use of the most suitable method of planning with least possible delay.

Initial Actions

On receipt of information regarding aircraft in difficulties normally from the Watch Supervisor in the ATCC, or from request of assistance from RSCs, MRCC (vessel or person - maritime distress) or from any adjacent RCCs and is aware that assistance is required the SMC shall act as follows:

- *Activate the SAR operation room;*
- *Appraise the situation.*

Continue to take the following actions if emergency situation involves civil aviation accident:

- *Declare the Distress phase if not done yet by the Duty Watch Supervisor;*
- *Notify the SAR Chief and the SAR Co-ordinator (SC);*
- *Request Supervisor to recall SAR trained staff if deemed necessary;*
- *Initiate ARCC activation message;*
- *Assign specific position accordingly (SMC, ASMC… etc.);*
- *Initiate NOTAM[25] actions;*

[25] *NOTAM (Notice to Airmen) - A notice issued by, or with the authority of the State and containing information or instruction concerning the establishment, condition change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to persons concerned with flight operations. NOTAM is distributed by AFTN. (Aeronautical Fixed Telecommunication Network).*

- *Initiate RQS[26] request from AIS[27] and weather report from Meteorological Office if not done yet by the Supervisor;*
- *Obtain information of aircraft position if necessary by:*
  - *Information contained in the flight plan or notification;*
  - *Check all airports or possible alighting areas along the route of flight and within the possible flight range of the aircraft concerned;*
  - *Notify other aircraft or agencies to attempt establishment of the aircraft's position, informing them of all known frequencies, request for aircraft lookout made through the ATCC Watch Supervisor);*
  - *Notify the Police, along the route of flight, and request them to verify alighting areas, or obtain information on the aircraft and its occupants;*
  - *Request MRCC[28] to alert the vessels in the area if the flight is over or near water;*
  - *Ascertain the type of emergency equipment carried by the missing or distressed craft;*
  - *When required, request Radar assistance for search from appropriate radar station or Radar Plot.*

8) Recorded Telephone Conversations

From the recorded telephone conversations between the KL ACC Radar Controller and MAS Operations Centre, the Radar Controller at 2123:18 UTC [0523:18 MYT] indicated that he would inform the Watch Supervisor to check on when was the last contact with MH370.

[26] RQS - Request Supplementary Flight Plan.

[27] AIS - Aeronautical Information Service.

[28] MRCC - Maritime Rescue Coordination Centre.

9) Watch Supervisor Air Traffic Services and Sector (3 & 5) Logbook

MATS Part 1 - Admin, page 1-1-7 para 1.7 for recording of entries in the logbook as follows:

a) *The time of entries shall be based on UTC and events recorded in a chronological order;*

b) *Entries shall give sufficient details to give readers a full understanding of all actions taken;*

c) *The time an incident occurred and the time at which each action was initiated shall be stated.*

10) Flight Progress Strip

The FPS (*Figure 1.18D* below) of MH370 on 07 March 2014.contains essential flight and control data and is the basic tool to enable Air Traffic Controllers to visualise the disposition of traffic within their area of responsibility including traffic arriving and departing an aerodrome, assess conflicts and control aircraft in a safe manner.

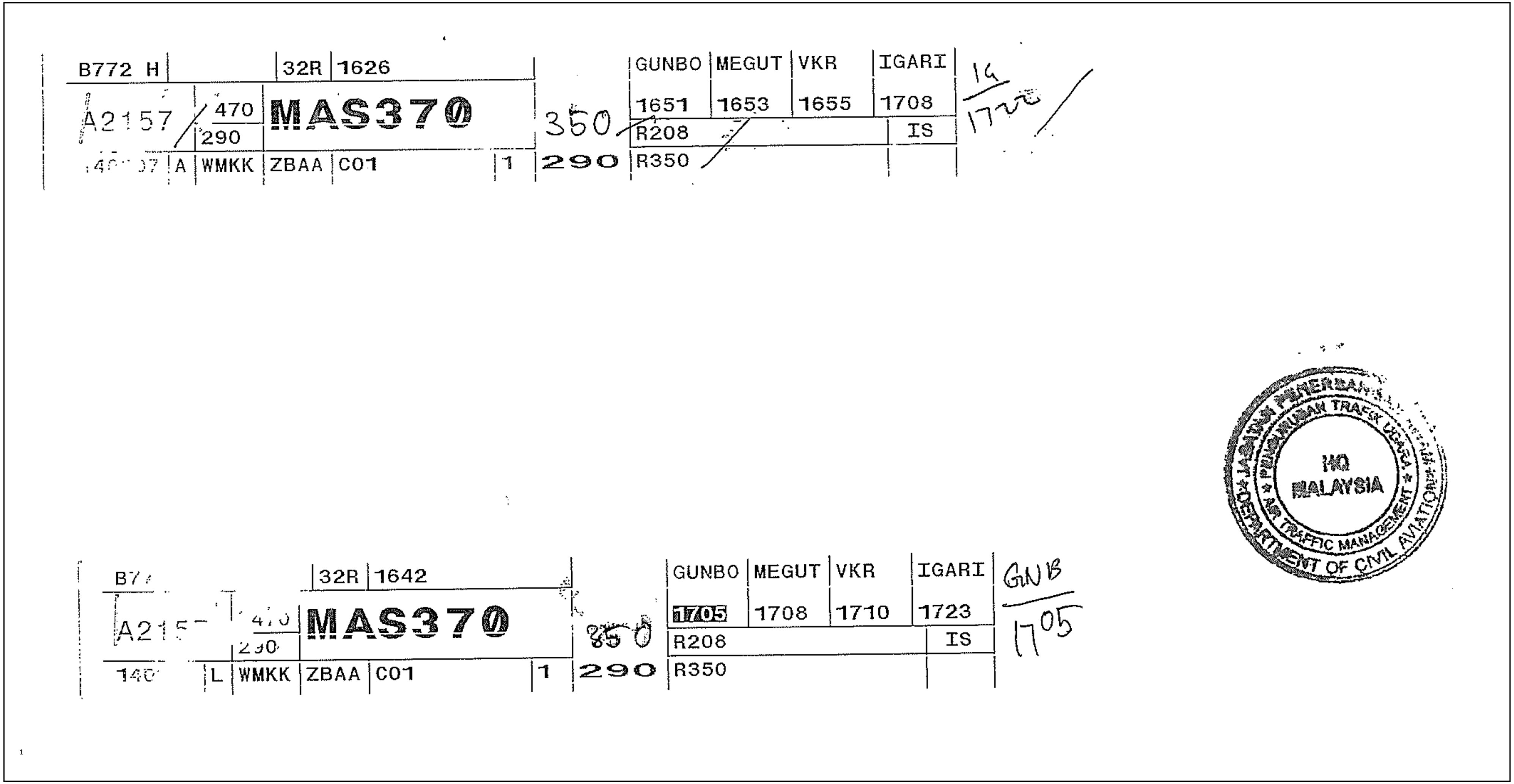


Figure 1.18D - Flight Progress Strip of MH370 on 07 March 2014

1.18.2 Aircraft Cargo Consignment

1) Introduction

During the course of the investigation the Team visited and interviewed the relevant people in MAS at KLIA Sepang, Motorola Solutions Penang, MASkargo Sdn. Bhd. (MASkargo) Penang, NNR Global Logistic (M) Sdn. Bhd. Penang, Poh Seng Kian, Muar, Johore (supplier of mangosteen fruit), Freescale Semiconductor, Petaling Jaya, JHJ International Transportation Co. Ltd. Beijing, China (forwarding agent of Motorola Solutions China), Motorola Solutions China, TianJin, China and Beijing GuangChangMing Trading Co. Ltd. Beijing, China.

On 08 March 2014, MAS B777-200ER MH370 was on a scheduled flight from KLIA to Beijing, China. The aircraft was carrying 227 passengers with a tabulated passenger weight of 17,015 kg, baggage 3,324 kg, cargo 10,806 kg (gross weight) and Max Take-off Weight of 223,469 kg. All these are stipulated in the cargo manifest attached as *Appendix 1.18H*.

The lists of cargo, Airway Bill, Local Agent and Final Destination, are tabulated in *Table 1.18F (*below).

The cargo that had generated interest were:

- Lithium ion Batteries (Li-Ion) and Accessories - 2,453 kg; and
- Mangosteens - 4,566 kg.

No.	COMPANY (MALAYSIA)	AIRWAY BILL	AGENT TRANSPORTER (MALAYSIA)	ITEMS	WEIGHT (nett)
1.	Grolier (M) SB Balakong Selangor	232-2009141	Kerry Logistics (M) Subang Jaya, Selangor	Scholastic assorted books	2,250 kg
2.	Motorola Solutions (M) Bayan Lepas Penang	232-0677085	NNR Global Logistic Batu Maung Penang	Lithium Ion batteries- walkie-talkie accessories & chargers	2,453 kg
3.	Panasonic Industrial Devices Sales, Shah Alam, Selangor	232-12022382	Panalpina Transport (M) MAS Cargo, KLIA,	Electrical parts capacitors	26 kg
4.	Freescale Semiconductor Petaling Jaya, Selangor	232-12022404	Panalpina Transport (M) MAS Cargo, KLIA	Vehicle electronic chips	6 kg
5.	Agilents Technologies Bayan Baru, Penang	232-10664905	Kintetsu World Express MAS Cargo Penang	Electronic measurements	646 kg
6.	Poh Seng Kian Muar, Johore	232-12007306	Poh Seng Kian Muar, Johore	Fresh mangosteens	4,566 kg
7.	Malaysian Express Worldwide, Subang Jaya Selangor	232-11873632	Malaysian Express Worldwide, Subang Jaya, Selangor	Courier materials - documents	6 kg

Table 1.18F - List of Cargo on Board MH370

2) Lithium Ion Batteries

Li-Ion Batteries carried on MH370 were from Motorola Solution Penang. Of the total consignment of 2,453 kg, only 221 kg were Li-ion batteries, the rest were chargers and radio accessories.

The batteries were fabricated in the factory before being packed for export. *Figure 1.18E* (below) shows a raw single cell battery.

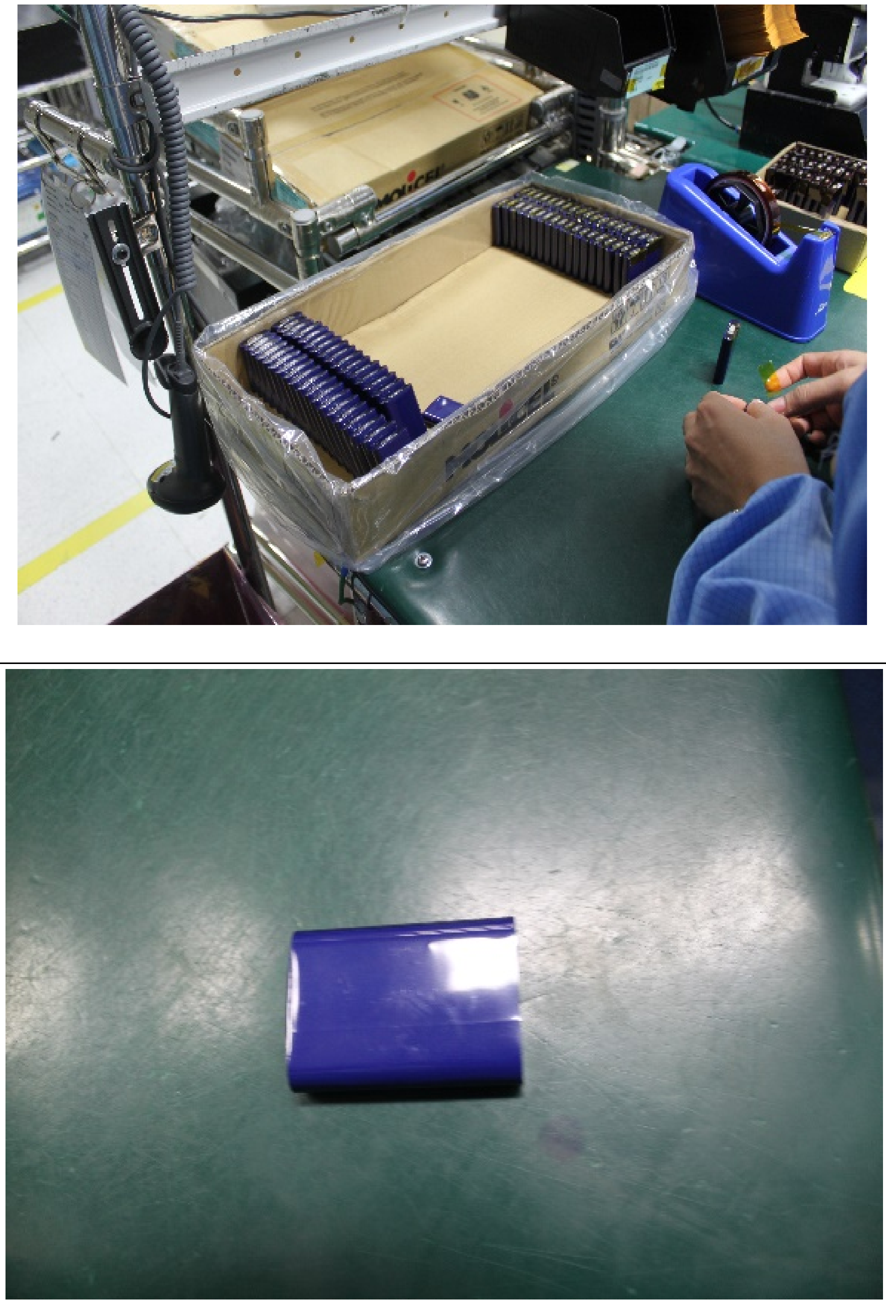


Figure 1.18E - Raw Single Cell Battery

The step-by-step process of fabricating 2 single cell batteries together to form a battery pack for shipment is shown in *Figure 1.18F* (below).

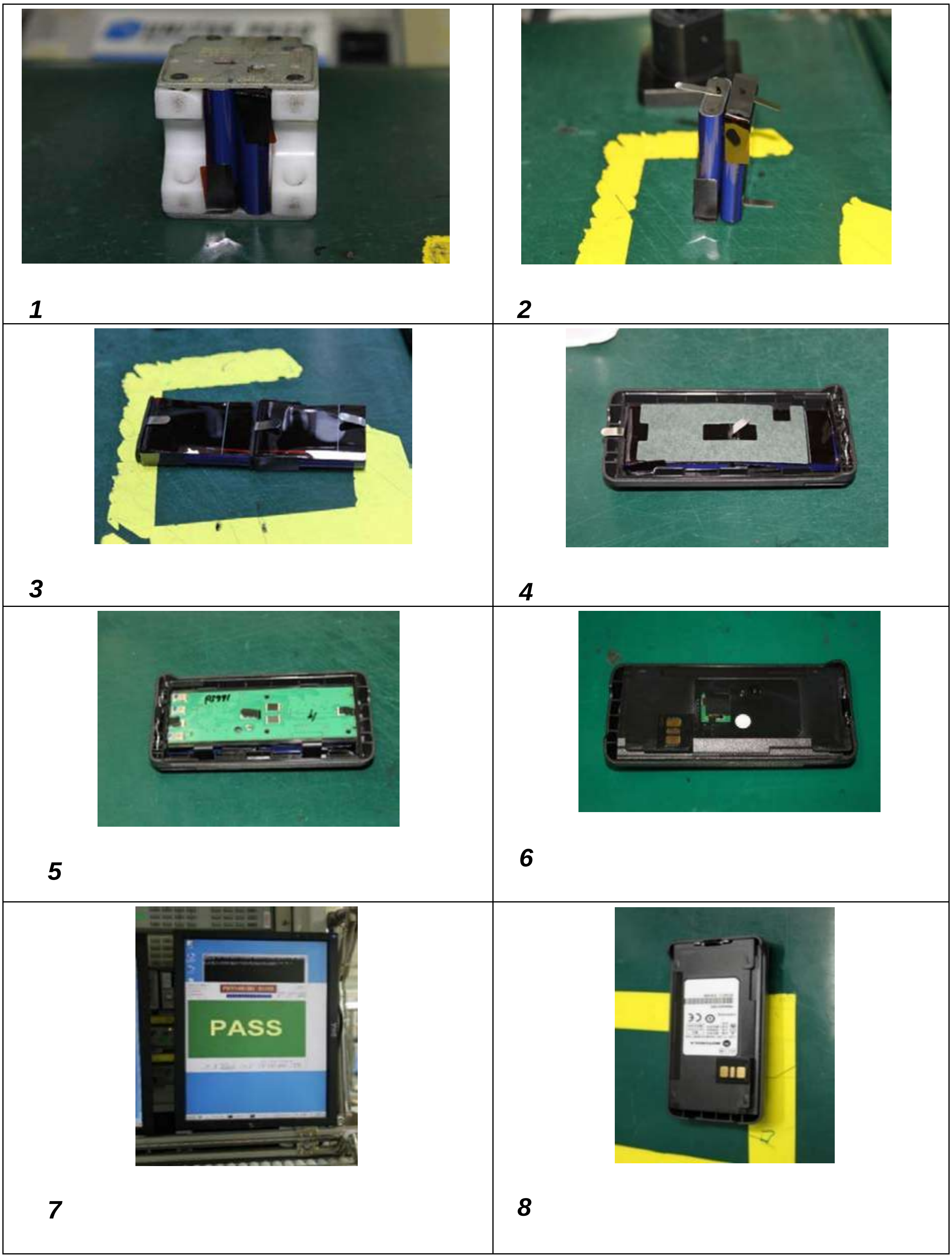


Figure 1.18F - Step-by-step Process of Fabricating 2 Single Cell Batteries to form a Battery Pack for Shipment

The Li-Ion batteries from Motorola Solutions Penang were assembled on 07 March 2014 before being packed, the built-up consigments placed on wooden pallets and delivered by the forwarding agent (NNR Global Logistic (M) Sdn. Bhd.) to MASkargo Penang and subsequently transported by MASkargo truck '*MH6803*' to MAS Cargo Complex, KLIA, Sepang. The shipment did not go through security screening in Penang but was inspected physically by MASkargo personnel and went through Customs' inspection and clearance before the truck was sealed and allowed to leave the Penang Cargo Complex.

The shipment arrived at KLIA Cargo Complex on the evening of 07 March 2014 before being loaded onto MH370 without going through additional security screening.

The Motorola Solutions consignments were loaded in the Aircraft at 90348C (47R) and PMC5871 (23L, 23R) as per Loading Instruction/Report. Illustration as shown in *Figure 1.18G* (below).

There were two (2) different models of Li-Ion battery consignment on MH370 on 08 March 2014:

- PMNN4073AR Li-ion batteries rated at 7.4V, 11.8Wh; and
- PMNN4081BRC Li-ion batteries rated at 7.4V, 11.1Wh.

Both of the batteries were not regulated as Dangerous Goods because the packing had adhered to the guidelines as per Lithium Battery Guidance Document (3. Section II - Packing Instructions 965-970). This document is based on the provisions set out in the 2013-2014 Edition of the ICAO Technical Instructions for Safe Transport of Dangerous Goods by Air and the 55th Edition of the IATA Dangerous Goods Regulations (DGR). The ICAO and IATA documents are as per *Appendix 1.18I.*

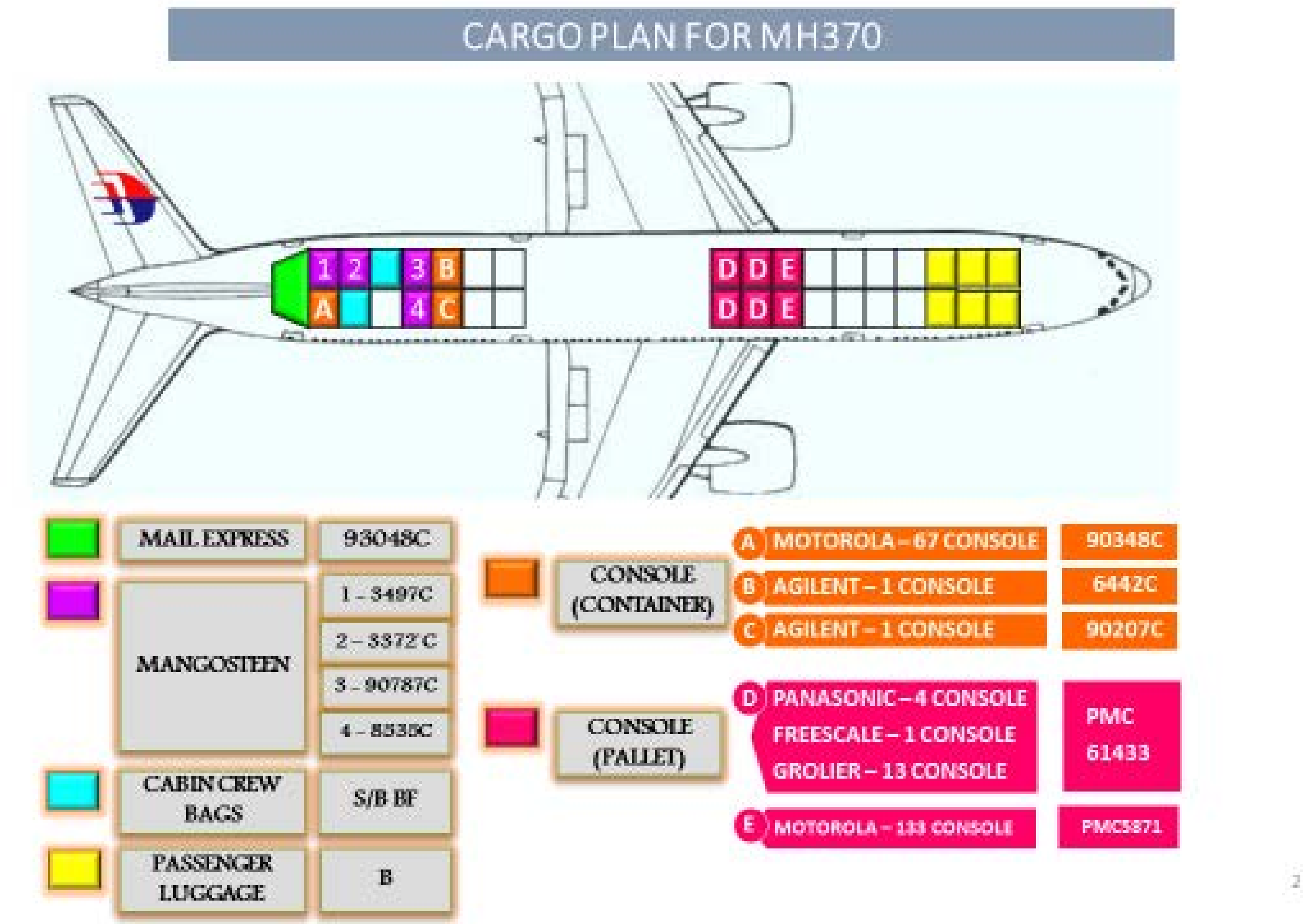
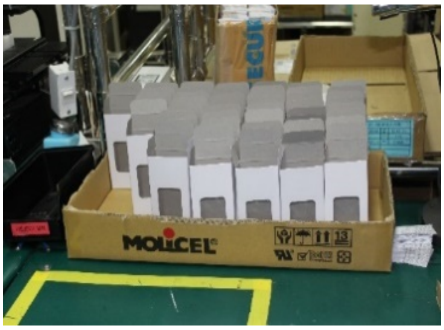


Figure 1.18G - Motorola Solutions Consignment Loading

The packing of the batteries by Motorola Solutions is shown in *Figure 1.18H* (below).

Picture 1



Picture 2

Picture 3

Picture 4

Picture 5

Picture 6

Figure 1.18H - Packing of Batteries by Motorola Solutions

Each Li-Ion battery was placed in a white window box (*Picture 1* [above]) and two of these filled boxes were then placed in a brown box (*Picture 2* [above]) printed with Li-Ion battery warning shipping information (*Picture 3* [above]). The brown box filled with two Li-Ion batteries each was then packed into a larger box. Each box contained twenty-four Li-ion batteries (12 boxes x 2 = 24, *Picture 4, Figure 1.18H* [above]), sealed and weighed (*Picture 5, Figure 1.18H* [above]). All the sealed boxes were placed on a wooden pallet and the built-up consignment was wrapped with plastic and polystyrene sheets for protection (*Picture 6, Figure 1.18H* [above]). They were then scanned, with the number of batteries determined by means of weighing the boxes.

From January 2014 to May 2014 there were ninety-nine shipments of Li-ion Batteries on MAS flights to Beijing.

Refer *Appendix 1.18J - List of Airways Bills.*

3) Mangosteen Fruits

The mangosteens on board MH370 on 08 March 2014 originated from Poh Seng Kian of No.79, 6¼ mile Kesang, 84000 Muar, Johore, Malaysia. About 2,500 kg of the fruit were harvested from Muar and the rest from Sumatra, Indonesia. Photographs of the mangosteen orchard and a typical mangosteen plant are shown as *Figures 1.18I* and *1.18J* (below) respectively.

Figure 1.18I - Mangosteen Orchard in Muar, Johor, Malaysia

Figure 1.18J - Mangosteen Plant/Fruit

The mangosteens were packed in plastic baskets of between 8 to 9 kg per basket with a piece of sponge soaked with water placed on top of the mangosteens to maintain their freshness (*Figures 1.18K and 1.18L* [below]*)*. The packed mangosteens were then loaded on the trucks which proceeded to MASkargo Complex at KLIA, Sepang. At the complex, four ULD containers were provided by MASKargo staff to the forwarding agent. The forwarding agent then loaded the packed fruit into the ULD containers (*Figure 1.18M* [below]). The consignment was then inspected by the Federal Agriculture Marketing Authority (FAMA) of Malaysia. After obtaining the clearance, the forwarding agent handed over the consignments to the MAS loaders for loading into the aircraft.

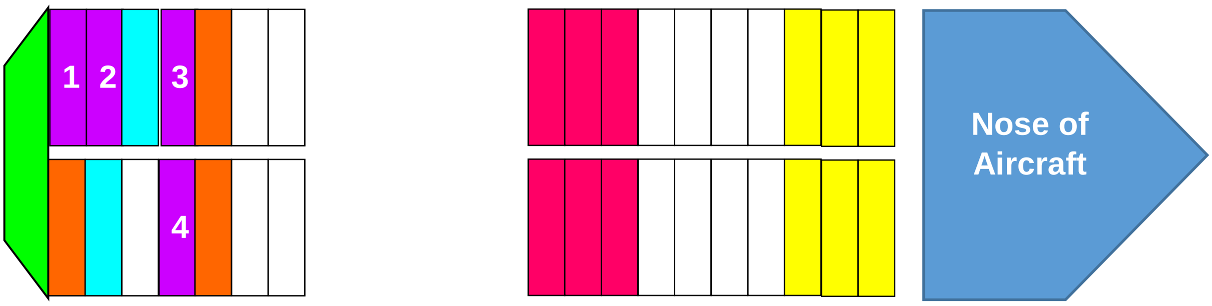
Figure 1.18K - Plastic Baskets of Mangosteens

Figure 1.18L - Piece of Soaked Sponge placed on Top of Mangosteens

		
1. MASkargo Perishable Warehouse	**2.** Unloading crates of mangosteens from plantation	**3**. Crates of mangosteens ready for loading into ULD
		
4. Placing large plastic sheet in ULD before loading	**5**. Loading crates of mangosteens into ULD	**6**. Filling up crates into ULD .
		
7. Secured crates of mangosteens with plastic sheets before latching ULD cover.	**8**. Another piece of plastic sheet to cover ULD	**9.** ULD secured with labels for uploading into aircraft

Figure 1.18M - Processing of Packed Crates of Mangosteens into ULD before Uploaded to Aircraft

Flight MH370 on 08 March 2014 carried four ULD containers of mangosteens - ULD AKE3497MH weighing 1,128 kg was placed at cargo bay 41L, ULD AKE90787MH weighing 1,152 kg at cargo bay 41F, ULD AKE3372MH weighing 1,148 kg at cargo bay 43L and ULD AKE8535MH weighing 1,138 kg at cargo bay 44L. The loading arrangement is shown in *Figure 1.18N* (below). Loading Instruction/Report is shown in the MH370 cargo manifest (*Appendix 1.18H*).



No.	ULD	WEIGHT (KG)	POSITION
1	AKE3497MH	1,128	41F
2	AKE90787MH	1,152	41L
3	AKE3372MH	1,148	43L
4	AKE8535MH	1,138	44L

Figure 1.18N - Loading Arrangement of ULDs of Mangosteens

From January 2014 till May 2014 there were a total of eighty-five shipments of mangosteens to Beijing, China. The list of Airway Bills is shown in *Appendix 1.18J*. The combination of the two cargo shipments (Li-ion Batteries and mangosteens) carried together from January to May 2014 were thirty-six times (*highlighted in red in Appendix 1.18J).*

1.18.3 Crew and Passengers on Board MH370

1) Total Number of Crew and Passengers

Total number crew and passengers on board MH370 are shown in *Table 1.18G* (below).

Crew		Passengers	Total
Flight	Cabin		
2	10	227	239

Table 1.18G - Total Number of Crew and Passengers

2) Nationalities of the Crew and Passengers

The nationalities of the flight crew and passengers on board MH370 are shown in *Table 1.18H* (below).

Countries		Crew		Passengers	Total
		Flight	Cabin		
1.	China	-	-	153	153
2.	Malaysia	2	10	38	50
3.	Indonesia	-	-	7	7
4.	Australia	-	-	6	6
5.	India	-	-	5	5
6.	France	-	-	4	4
7.	United States of America	-	-	3	3
8.	Ukraine	-	-	2	2
9.	Canada	-	-	2	2
10.	New Zealand	-	-	2	2
11.	Netherland	-	-	1	1
12.	Russia	-	-	1	1
13.	Chinese Taipei	-	-	1	1
14.	Italy* (Iran)	-	-	1	1
15.	Austria* (Iran)	-	-	1	1
Total		2	10	227	**239**

Table 1.18H - Breakdown of Nationalities of Passengers

* Travelling on stolen passports and discovered to be Iranian citizen *(Figures 1.18V & W* [below] *on Passengers' Seating Positions).*

a) Crew

All the 12 crew (including the two pilots) were Malaysians.

b) Passengers

A total of 227 passengers (including 3 children and 2 infants) were on board with the majority of them from China, followed by Malaysia and other citizens from different countries.

c) Passengers' Seating Positions

The aircraft was compartmentalised into 2 categories of seating, namely the business class with a total of 35 seats and the economy class with a total of 249 seats. Passengers from the 14 countries were seated throughout the aircraft from Row 1 to Row 41. (*Figure 1.18O* [below]).

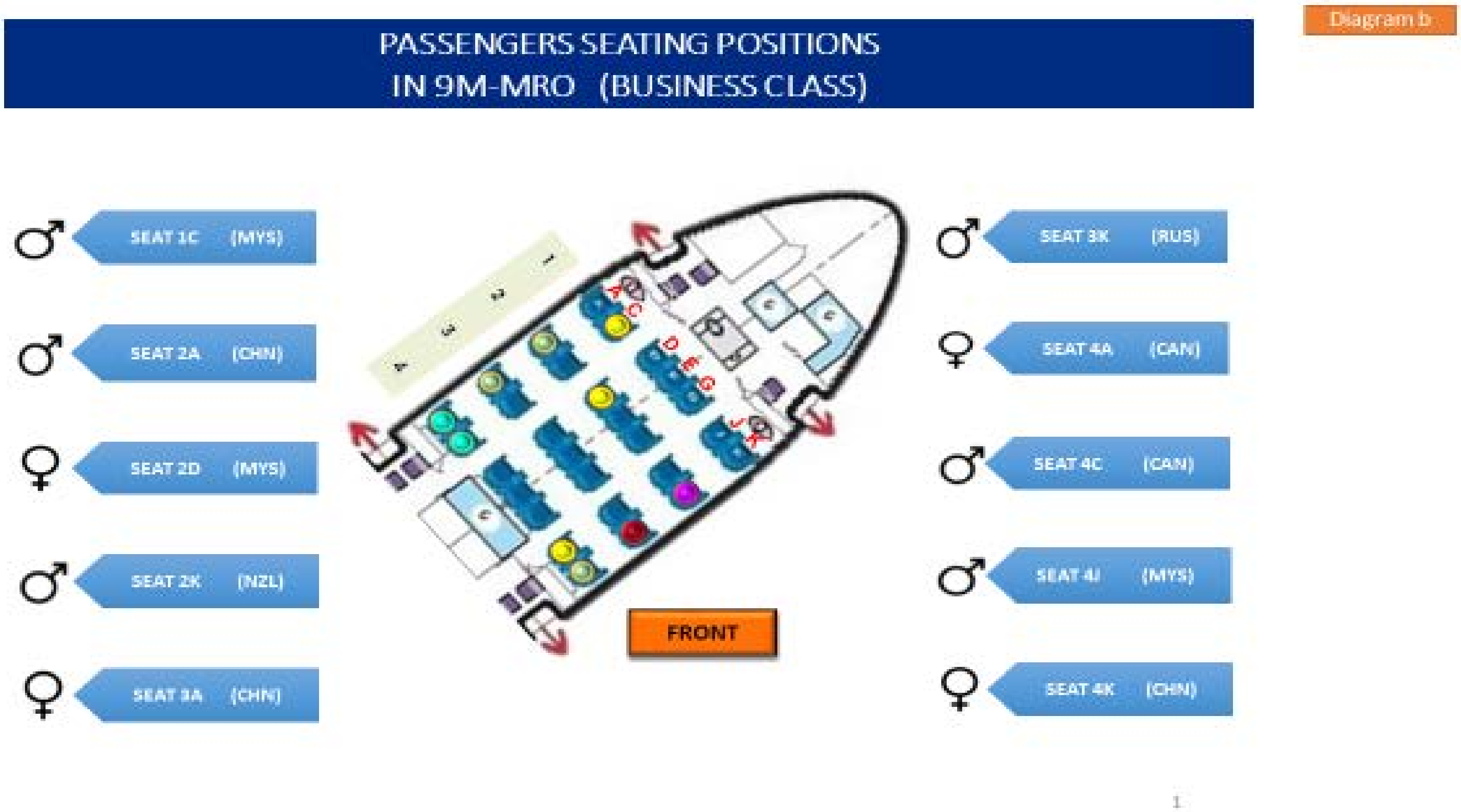
A total of 10 passengers were seated in the Business Class in the front portion of the aircraft, from Row 1 to Row 4. (*Figure 1.18P* [below]).

In the middle portion of the aircraft, the Economy seating started from Row 11 to Row 27. A total of 127 passengers were seated in this middle portion of the aircraft. There were 2 children on seats 17F and 18F respectively (*Figures 1.18Q, 1.18R, 1.18S and 1.18T* [below]).

The rear portion of the aircraft accommodated 90 passengers from Row 29 to Row 41. 2 infants were on board accompanied by adults seated on seats 30E and 37D respectively. There was a child on seat 30H in the rear portion of the aircraft. (*Figures 1.18U, 1.18V and 1.18W* [below]).

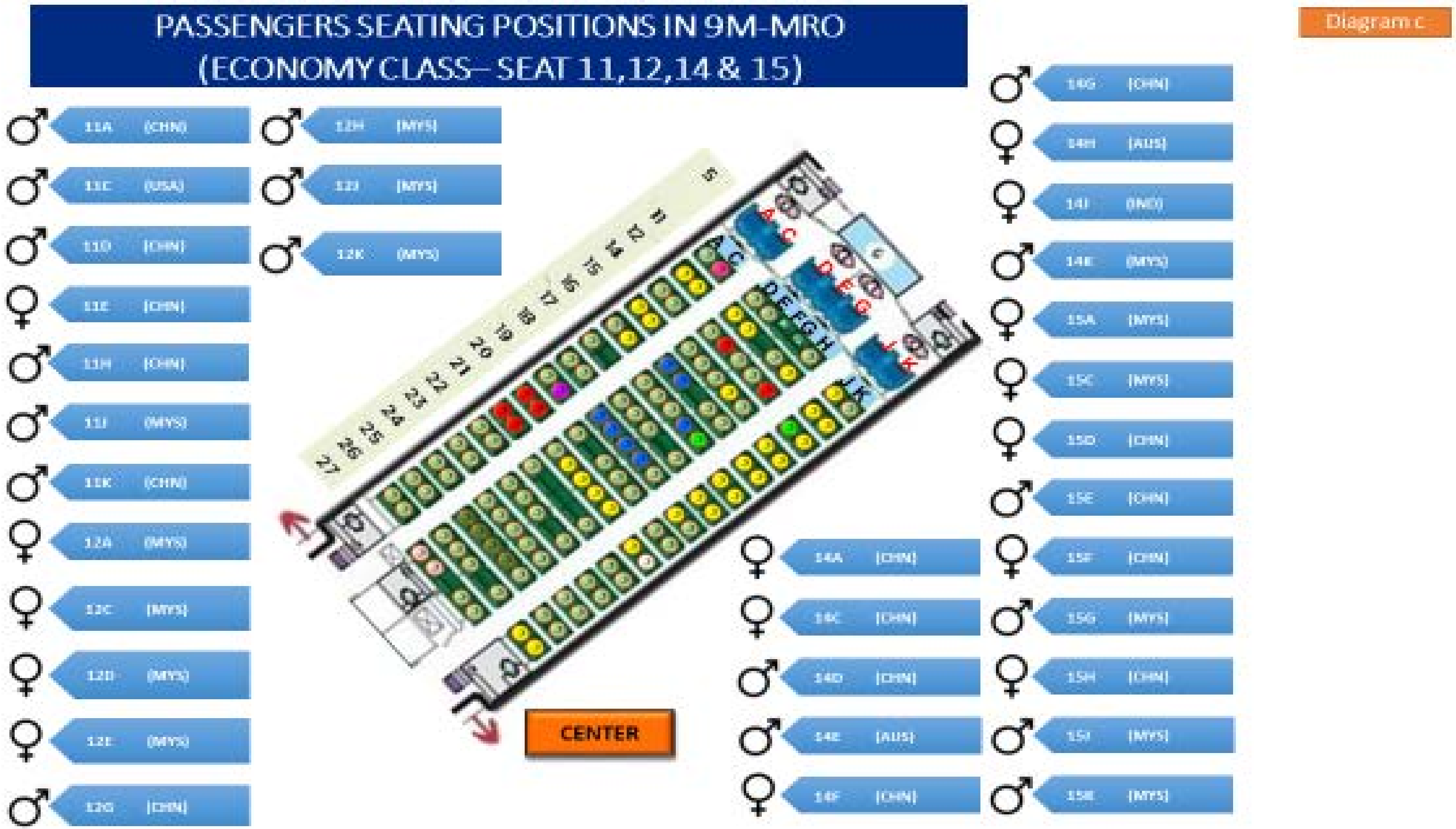
Source: Royal Malaysia Police

Figure 1.18O - Passengers' Seating Positions



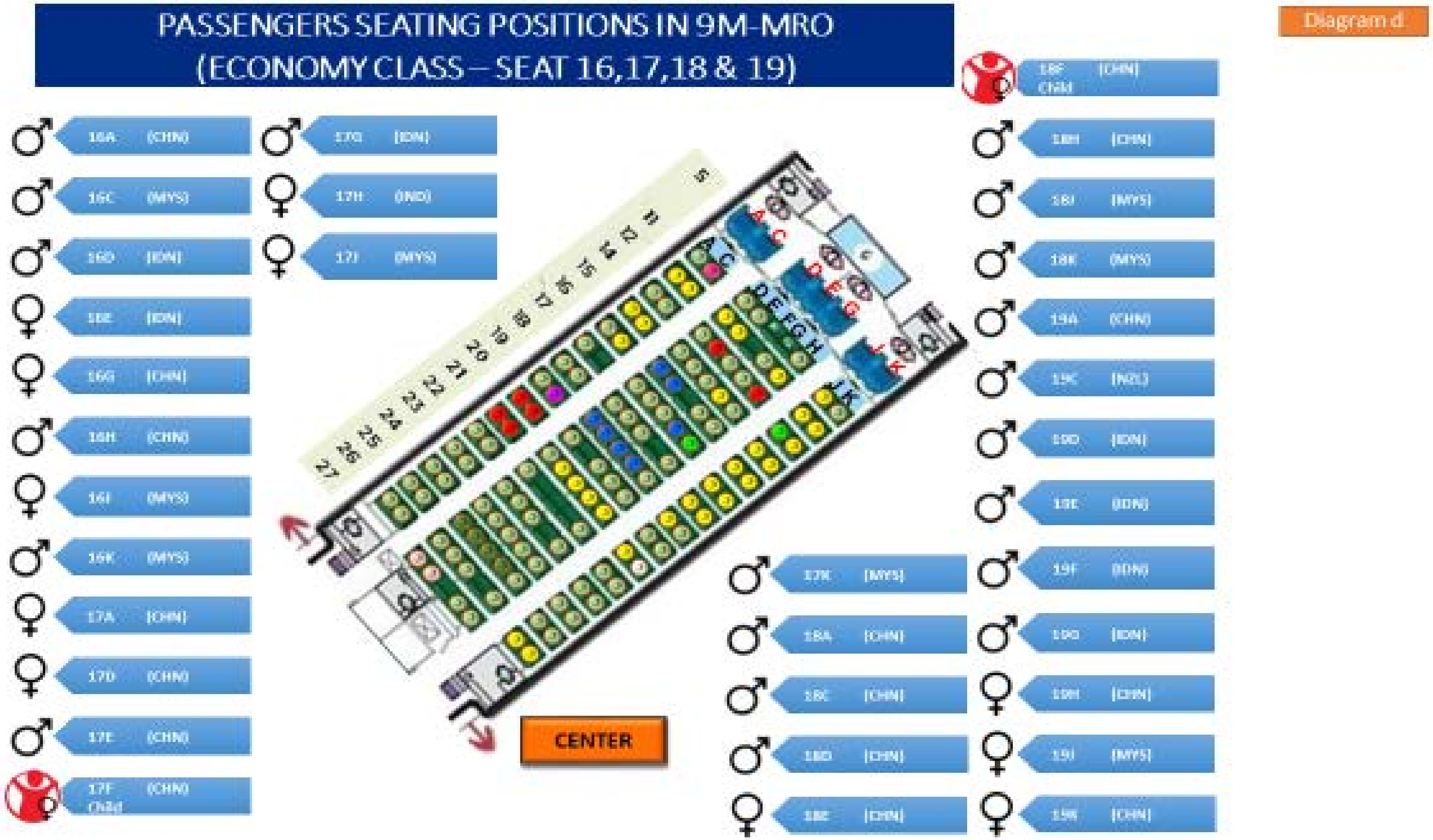
Source: Royal Malaysia Police

Figure 1.18P - Passengers' Seating Positions (Business Class)



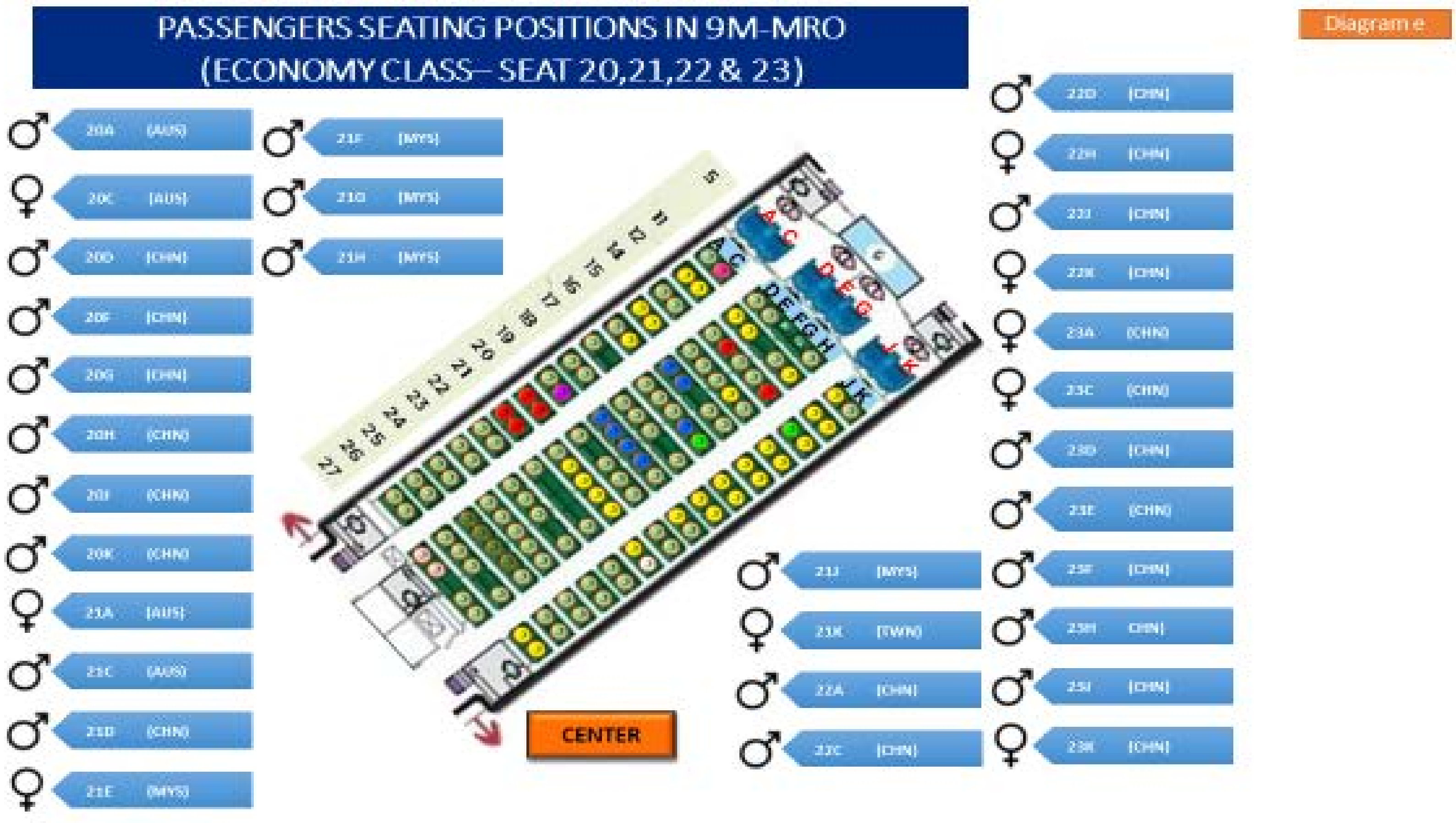
Source: Royal Malaysia Police

Figure 1.18Q - Passengers' Seating Positions (Economy Class - Seats 11, 12, 14 & 15)



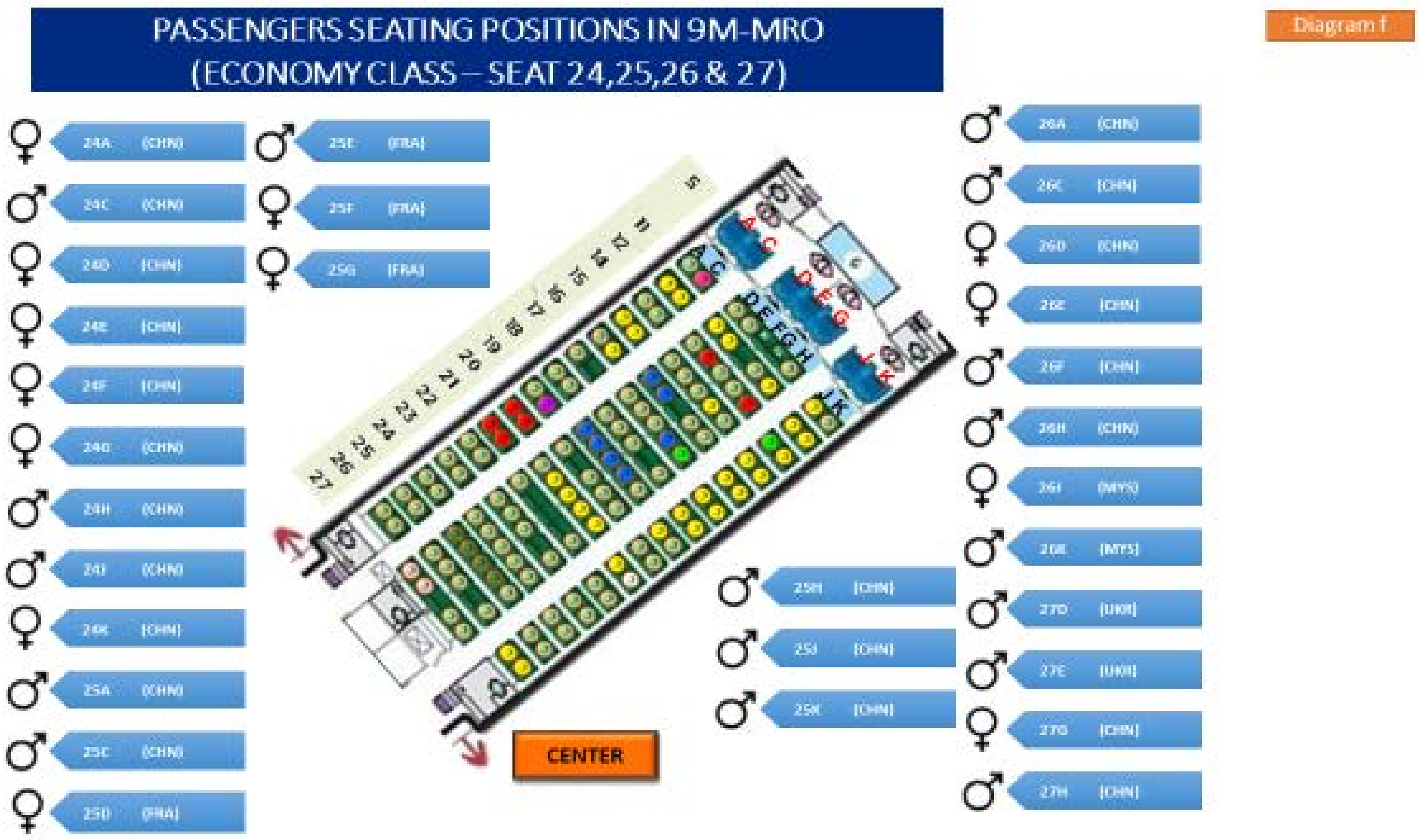
Source: Royal Malaysia Police

Figure 1.18R - Passengers' Seating Positions (Economy Class - Seats 16, 17, 18 & 19)



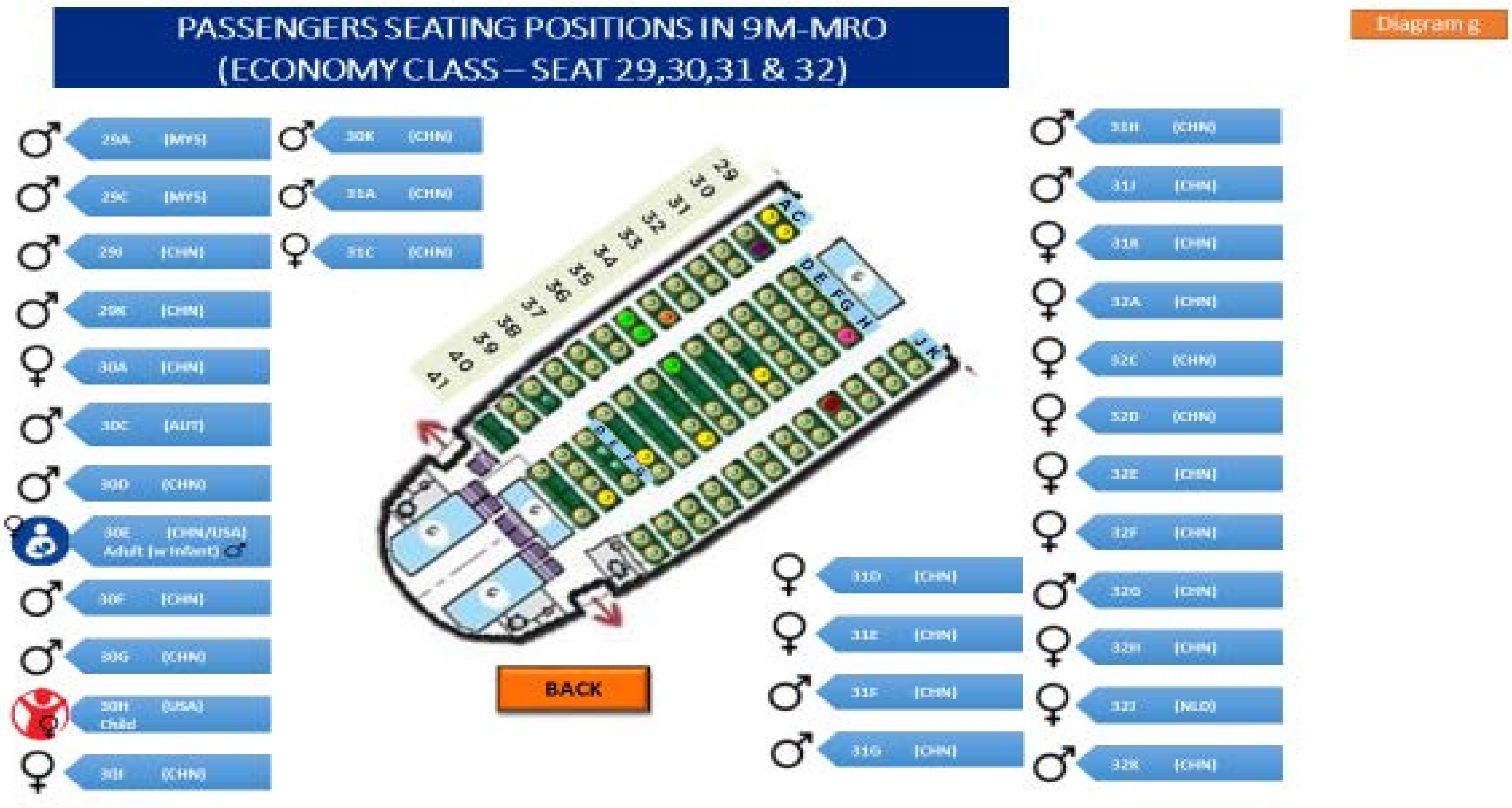
Source: Royal Malaysia Police

Figure 1.18S - Passengers' Seating Positions (Economy Class - Seats 20, 21, 22 & 23)



Source: Royal Malaysia Police

Figure 1.18T - Passengers' Seating Positions (Economy Class - Seats 24, 25, 26 & 27)

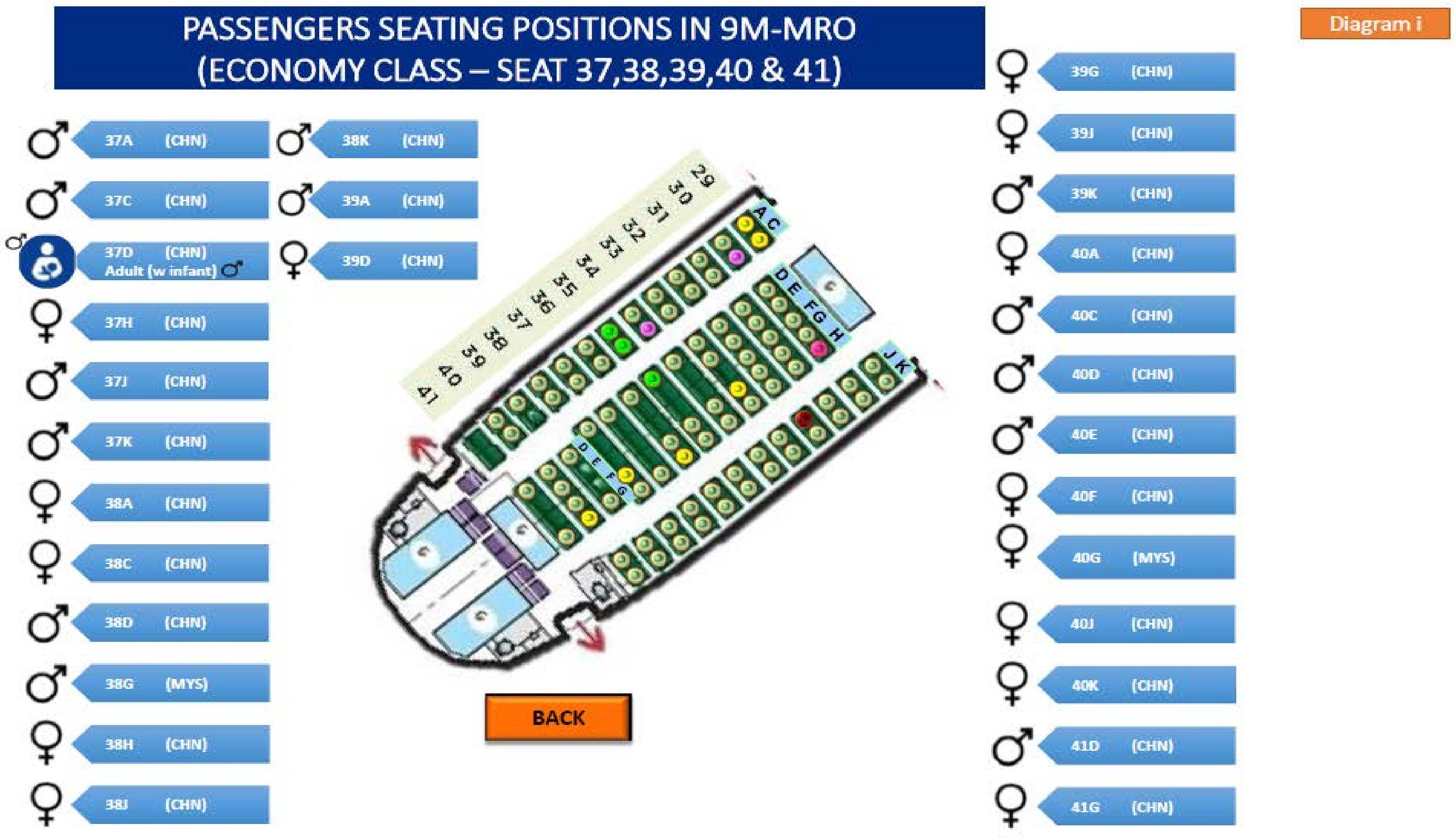


Source: Royal Malaysia Police

Figure 1.18U - Passengers' Seating Positions (Economy Class - Seats 29, 30, 31 & 32)

Source: Royal Malaysia Police

Figure 1.18V - Passengers' Seating Positions (Economy Class - Seats 33, 34, 35 & 36)



Source: Royal Malaysia Police

Figure 1.18W - Passengers' Seating Positions (Economy Class - Seats 37, 38, 39, 40 & 41)

SECTION 1 – FACTUAL INFORMATION

1.19 NEW INVESTIGATION TECHNIQUES

Not applicable.

SECTION 2 – ANALYSIS

INTRODUCTION

Section 2 analyses the relevant issues associated with the disappearance of B777-200ER aircraft, registered as 9M-MRO, and operating as Flight MH370 on 08 March 2014. Recognising that at the time of issue of this Report, the main aircraft wreckage, including the Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) have not been located, this analysis will necessarily be limited by a significant lack of evidence.

The issues that will be covered in this Section include the following:

1. Diversion from Filed Flight Plan Route;
2. Air Traffic Services Operations;
3. Flight Crew Profile;
4. Airworthiness & Maintenance and Aircraft Systems;
5. Satellite Communications;
6. Wreckage and Impact Information;
7. Organisation and Management of Department of Civil Aviation and Malaysia Airlines; and
8. Aircraft Cargo Consignment.

SECTION 2 – ANALYSIS

2.1 DIVERSION FROM FILED FLIGHT PLAN

2.1.1 Seven Simulator Sessions

To analyse further on how MH370 had diverted from the Filed Flight Plan (FPL) route, the Team conducted a total of seven flight simulator sessions to recreate the two turns of MH370, i.e. six sessions on the left turn past waypoint IGARI and one session on the right turn on reaching the south of Penang Island. Three of the seven sessions were conducted at high speed and the remainders at low speed. The turns were based on the recorded primary radar data that recorded a primary target conducting a left turn from where the SSR code ceased, shortly after the aircraft passed waypoint IGARI. The following data (*Tables 2.1A to 2.1F* [below] on data input for the first six sessions respectively) were introduced to simulate an actual environment:

- Actual weight and meteorological condition prevailing at the time of the turn (extracted from the computerised flight plan); and
- Different speed and rate of turns to determine scenarios closest were made available to the Team.

1) Recreating the Left turn past Waypoint IGARI – Session 1

Initial conditions

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 271 (475 knots ground speed)
Simulator setup	Speed/Lateral Navigation/Vertical Navigation (SPD/LNAV/VNAV), autopilot engaged, autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7

Table 2.1A - Data Input for Session 1

To get the 'aircraft' to track correctly, a flight path from waypoint IGARI to waypoint BITOD was generated with the entry and exit waypoints entered.

The simulation commenced before IGARI and the 'aircraft' turned right on LNAV and tracked to the entry waypoint. Once over the waypoint, the flight management computer (FMC) was directed to fly "direct to" to the exit waypoint. The 'aircraft' entered a left turn, with a maximum bank-angle of 26° (maximum bank-angle in LNAV is 25°).

About half-way through the turn, it was obvious that the 'aircraft' was not going to make it through the exit waypoint as it was overshooting as there was no tracking information in the FMC. The simulator session was then terminated.

2) Session 2

Initial conditions (identical to Session 1)

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 271 (475 knots ground speed)
Simulator setup	SPD/LNAV/VNAV, autopilot engaged, autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7
Additional waypoint	N05.15.6 E100.27.5

Table 2.1B - Data Input for Session 2

To get the 'aircraft' to track correctly, a flight path from waypoint IGARI to waypoint BITOD was generated with the entry and exit waypoint entered. A further waypoint was entered along a track of 244° at the commencement of the right turn south of Penang.

The simulation commenced before IGARI and the 'aircraft' turned right on LNAV and tracked to the entry waypoint. Once over the waypoint, the FMC was directed to fly "direct to", to the exit waypoint. The 'aircraft' entered a left turn, with a maximum bank-angle of 26° (maximum bank-angle in LNAV is 25°).

The ‘aircraft’ made the exit waypoint; however, it took 3 minutes and 45 seconds to achieve it (the recorded radar time was 2 minutes 10 seconds).

3) Session 3

Initial conditions

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 250 (425 knots groundspeed)
Simulator setup	SPD/LNAV/VNAV, autopilot engaged, autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7
Additional waypoint	N05.15.6 E100.27.5

Table 2.1C - Data Input for Session 3

Following discussions, it was decided to reduce the speed in the turn to see if the rate of turn would increase. In this session, the speed was reduced to 250 knots IAS (ground speed of 425 knots). Similar set up as Session 2.

The simulation commenced before IGARI and the ‘aircraft’ turned right on LNAV and tracked to the entry waypoint. Once over the waypoint, the FMC was directed to fly “direct to” to the exit waypoint. The ‘aircraft’ entered a left turn, with a maximum bank-angle of 28° (maximum bank-angle in LNAV is 25°). The ‘aircraft’ made the exit waypoint. However, it took 3 minutes and 3 seconds to achieve it.

4) Session 4

Following further discussions, it was decided to further reduce the speed in the turn.

The simulation commenced before IGARI and the ‘aircraft’ turned right on and tracked to the entry waypoint. Once over the waypoint, the FMC was directed to fly “direct to”, to the exit waypoint. The ‘aircraft’ entered a left turn, with a maximum bank-angle of 23° (maximum bank-angle in LNAV is 25°).

Initial conditions

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 220 (400 knots groundspeed)
Simulator setup	SPD/LNAV/VNAV, autopilot engaged, autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7
Additional waypoint	N05.15.6 E100.27.5

Table 2.1D - Data Input for Session 4

The 'aircraft' made the exit waypoint. However, it took 3 minutes and 30 seconds to achieve it.

5) Session 5 (Manual Flying)

Following discussions, it was agreed that the turn could be executed in LNAV, but not in 2 minutes. It was decided that the bank-angle needed to be increased to reduce the time and that could only be achieved with the autopilot disengaged and the 'aircraft' manually flown, with the auto-thrust managing the speed. Similar set-up as Session 2.

Initial conditions

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 271 (475 knots ground speed)
Simulator setup	SPD/LNAV/VNAV, autopilot engaged, then autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7
Additional waypoint	N05.15.6 E100.27.5

Table 2.1E - Data Input for Session 5

The simulation commenced before IGARI with autopilot and autothrottle engaged and the 'aircraft' turned right on LNAV and tracked to the entry waypoint. Once over the waypoint, the autopilot was disconnected and the 'aircraft' manually turned to the left. Bank-angles around 30°-32° were used. As the entry and exit waypoints were displaced slightly laterally (i.e. not exactly aligned 180° apart), the 'aircraft's wings were rolled level when aligned to intercept the exit waypoint. This was at 2 minutes and 10 seconds. The 'aircraft' then intercepted the exit waypoint at 2 minutes and 40 seconds.

6) Session 6 (Manual Flying)

Finally, it was agreed that the same turn should be executed manually but at a lower speed of 250 knots with the autopilot disengaged and the 'aircraft' manually flown, with the autothrottle managing the speed. Same set-up as Session 2.

Initial conditions

Fuel	41,200 kg
Gross weight	215,410 kg
Height	35,000 ft
Speed	IAS 250 (425 knots ground speed)
Simulator setup	SPD/LNAV/VNAV, then autopilot disengaged, autothrottle engaged
Entry waypoint	N07.05.7 E103.47.1
Exit waypoint	N07.12.7 E103.38.7
Additional waypoint	N05.15.6 E100.27.5

Table 2.1F - Data Input for Session 6

The simulation commenced before IGARI with autopilot and autothrottle engaged and the 'aircraft' turned right on LNAV and tracked to the entry waypoint. Once over the waypoint, the autopilot was disengaged and the 'aircraft' manually turned to the left. Bank-angle around 35° was used (bank-angle warnings sounded several times).

At about half way through the turn (1 minute mark), the stick-shaker activated. The 'aircraft' intercepted the exit waypoint at 2 minutes and 28 seconds.

7) Analysis on Re-enactment Sessions (Sessions 1 - 6)

a) From the various re-enactment sessions tested, it is apparent that the 'aircraft' could make the turn in LNAV, but took a longer time due to bank-angle limitations (25°) and also required the need to reduce speed (Session 3 was the closest at 3 minutes and 3 seconds) in the turn.

b) However, there were issues with the entry waypoint being off the direct track IGARI to BITOD (to the south-east) and this resulted in the 'aircraft' being in a slight right bank when overflying the waypoint and then starting the left turn. This would have increased the time to make the left turn as the 'aircraft' had to roll through level, before rolling west.

c) The 'aircraft' could also make the turn and achieve a closer time to the recorded radar data with the autopilot disengaged and manually flown (Session 5 was closest with 2 minutes 10 seconds to wings-level and 2 minutes and 40 seconds to the exit waypoint).

d) Again, there were issues with the positioning of the entry and exit waypoints as they were not aligned (i.e. not 180° apart) leaving a short straight segment before the 'aircraft' intersected the exit waypoint.

e) Summary of 6 Simulator Re-enactment Sessions and Common Factors

Based on the six simulator re-enactment sessions conducted as summarised in *Table 2.1G* (below) and on the common factors in *Table 2.1H* (below), the Team concluded the following:

i) The turn would have been carried out with the autopilot disengaged, as it was not possible to achieve a turn time of 2 minutes and 10 seconds (as suggested by recorded data) using autopilot. The manoeuvre can be performed by a single pilot. The Team also noted that the aircraft's flight path from after the turn was consistent with the navigation being set to LNAV and/or heading mode, following published and/or manual waypoints that are not normally used with normal route (published airways between Kota Bharu and Penang).

Re-enactment	Session					
	1	2	3	4	5	6
Ground Speed (in knots)	475	475	425	400	475	425
Autopilot Engaged	✓	✓	✓	✓	x	X
Additional Waypoint	x	x	X	N05.15.6 E100.27.5	✓	✓
Bank angle (in degrees)	26º	26º	28º	23º	30-32º	35º
Exit Waypoint Time	Over-Shooting	2 min 45 sec	3 min 3 sec	3 min 30 sec	2 min 40 sec	2 min 28 sec

Table 2.1G - Re-enactment Sessions

Common Factors		
1.	Fuel	41,200 kg
2.	Gross Weight	215,410 kg
3.	Height	35,000 ft
4.	Entry Point	N07.05.7º E103.47.1º
	Exit Point	N07.12.7º E103.38.7º
5.	Autothrottle Engaged	

Table 2.1H - Common Factors

ii) From the data it was determined that the 'aircraft' was on heading mode that varied from 239º to 255º as it flew to the south of Penang where it continued westerly to Waypoint MEKAR where it finally disappeared completely at 1822:12 UTC [0222:12 MYT], about 10 nautical miles north of MEKAR.

iii) Based on the Team's review of the Military recorded radar display and printout, the aircraft's flight path could not be determined, and there is no evidence of rapid altitude and/or speed changes to indicate that MH370 was evading radar.

iv) Without further evidence, the reason for the transponder information from the aircraft ceasing could not be determined;

v) It is determined that only the transponder signal of MH370 ceased from the ATC Controller display whilst displays from other aircraft were still available; and

vi) There is also no evidence to suggest that the aircraft was flown by anyone other than the designated MAS pilots. However, the Team does not exclude the possibility of intervention by a third party.

8) Session 7 – Recreating the Right Turn South of Penang Island

Initial conditions

Fuel	36,000 kg
Gross weight	210,200 kg
Height	35,000 ft
Speed	IAS294 (525 knots groundspeed) M0.86 Note: A tailwind of 30 knots was needed to achieve this
Simulator setup	SPD/LNAV/VNAV, autopilot engaged, autothrottle engaged.
Entry waypoint	N05.15.6 E100.27.5
Exit waypoint	N05.12.0 E100.01.5

Table 2.1I - Data Input for Session 7

To get the 'aircraft' to track correctly (*Table 2.1I* [above]), both the entry and exit waypoints were entered, without a track between them in the FMC. The 'aircraft' was flown on heading mode to turn gently to intercept the exit waypoint.

The simulation commenced before the entry waypoint. Once crossing the waypoint, a heading change to the right was initiated to achieve a bank-angle of 5°. During the turn, the bank-angle was increased to a maximum of 10°. The exit waypoint was easily intercepted at 3 minutes and 5 seconds (the recorded radar time was 3 minutes). No further simulations were done on this turn.

2.1.2 Ho Chi Minh Air Traffic Services Operations

Based on the on-site interviews and briefing from the Team's visit to the Office of the Vietnamese Civil Aviation Authority in Ho Chi Minh City, it was noted that the radar position symbol for MH370 dropped from the radar display at 1720:59 UTC (0120:59 MYT). MH370 had not reached waypoint BITOD which is 37 nm from waypoint IGARI and based on the aircraft speed of 480 kt, it would take approximately five minutes for MH370 to travel from IGARI to BITOD.

The Direct Line Coordination Communication transcripts between KL ACC and Ho Chi Minh ACC suggested that there were uncertainties on the position of the aircraft. This could come about from the level of understanding of the English language. The HCM Duty Controller also could not communicate effectively during the interviews and an interpreter was there to assist him.

Reference:

Ho Chi Minh radar data recording, page 33 to 41 and page 51 to 61 of the Direct Line Coordination Communication KL ACC Sector 3+5 Planner (*Appendix 1.18G*) transcripts between Kuala Lumpur ACC and Ho Chi Minh ACC)

SECTION 2 – ANALYSIS

2.2 AIR TRAFFIC SERVICES OPERATIONS

2.2.1 Review of Flight MH370 before its Disappearance

1) The MH370 from Kuala Lumpur to Beijing was a normal daily scheduled flight. It took off at 1642 UTC [0042 MYT].

2) There was no indication of any unusual operations prior to departure and during the flight until the last secondary radar position symbol was recorded by ATC at 1721 UTC [0121 MYT] as detailed in *Table 2.2A - Chronological of events before disappearance of MH370* below.

3) Preparation of the flight was in order from the time the Filed Flight Plan[29] (FPL) message was filed and transmitted 12 hours before the flight.

4) The flight crew reported on time for duty and there was no delay in the departure of the flight (*Figure 2.2C* [below] - *Departure message*).

5) There was also no report of any significant or unusual health-related issues for the flight and cabin crew.

6) The radiotelephony speech segments from the cockpit with KL ACC were determined from the voice analysis of the ATC radiotelephony communications recording to be that of the FO before take-off and the PIC after take-off.

7) The transfer of control was effected three minutes before the estimate for IGARI. There was no recording of transmission (voice or in written form) of KL ACC informing HCM ACC (via direct land line) when MH370 was transferred 3 minutes earlier than the estimate for the Transfer of Control Point (TCP).

Note:

Based on reconstruction *(Section 2.1)* of the flight profile conducted on the B777 simulator, the flight would be at waypoint IGARI one minute earlier than the original estimate of 1722 UTC [0122 MYT].

[29] Filed Flight Plan – The flight plan as filed with an ATS unit by the pilot or his designated representative, without any subsequent changes.

2.2.2 Chronology of ATC Events before the Disappearance of Flight MH370

No.	Time	Event	Remarks
1.	0444 UTC [1244 MYT]	Filed Flight Plan (FPL) of scheduled flight of MH370 transmitted at 070444 UTC [071244 MYT], about 12 hours earlier over the Aeronautical Fixed Telecommunications Network (AFTN).	As required under Annex 10, Volume II.
		Flight planned on ATS/RNAV Routes R208 IGARI M765 BITOD L637 TSN… ZBAA.	Filed Flight Plan (*Figure 2.2A*)
2.	1450 UTC [2250 MYT]	PIC of MH370 signed in for duty.	As per operational requirements.
3.	1515 UTC [2315 MYT]	FO of MH370 signed in for duty.	
		MAS Operations Despatch Centre (ODC) released flight.	
4.	1625:52 UTC [0025:52 MYT]	Airway clearance request to Lumpur Airways Clearance Delivery.	
5.	1625:52 UTC [0025:52 MYT]	Airway clearance request to Lumpur Airways Clearance Delivery.	.
6.	1627:31 UTC [0027:31 MYT]	Pushback and start-up clearance request to Lumpur Ground.	As per operational requirements.
7.	1640:31 UTC [0040:31 MYT]	Lumpur Tower cleared MH370 for take-off.	
8.	1642 UTC [0042 MYT]	MH370 departed from Runway Three Two Right KLIA.	Departure message (*Figure 2.2C*)
9.	1642:53 UTC [0042:53 MYT]	Lumpur Departure cleared MH370 to climb to FL180 and to cancel the Standard Instrument Departure (SID) clearance by tracking direct to waypoint (*Figure 2.2A*) IGARI.	Normal ATC practice for track shortening.

Table 2.2A - Chronology of ATC Events before the Disappearance of Flight MH370

cont…

2.2.2 Chronology of ATC Events before the Disappearance of Flight MH370 *(cont.)*

No.	Time	Event	Remarks
10.	1643:31 UTC [0043:31 MYT]	KL ACC Sector 3+5 coordinated with HCM ACC via direct land line the estimate of MH370 for waypoint IGARI at 1722 UTC on [0122 MYT], request flight level 350 and the assigned SSR Code 2157.	As per Letter of Agreement between Malaysia and Viet Nam. (*Appendix 1.1A*)
11.	1646:39 UTC [0046:39 MYT]	MH370 transferred to Lumpur Radar (Sector 3+5).	As per operational requirement.
12.	1646:58 UTC [0046:58 MYT]	Lumpur Radar (Sector 3+5) cleared MH370 to climb to FL250.	As per operational requirement.
13.	1650:08 UTC [0050:08 MYT]	Lumpur Radar (Sector 3+5) cleared MH370 to climb to FL350.	
14.	1701:17 UTC [0101:17 MYT]	MH370 reported maintaining FL350.	It was noticed that the PIC made the same statement of "*maintaining flight level three five zero'* twice at 1701:17 UTC [0101.17 MYT] and at 1707:56 UTC [0107:56 MYT].
15.	1707:56 UTC- [0107:56 MYT]	MH370 reported maintaining FL350.	• However, the Team did not find any significance of that statement spoken twice by PIC in a short interval of 6.39 minutes.

Table 2.2A - Chronology of ATC Events before the Disappearance of Flight MH370

cont…

2.2.2 Chronology of ATC Events before the Disappearance of Flight MH370 *(cont.)*

No.	Time	Event	Remarks
15. *cont.*	1707:56 UTC- [0107:56 MYT]	MH370 reported maintaining FL350.	• Also refer *para. 2.2.9 para 1) a) (1-6)* on Radiotelephony Readback on frequency changes for more details.
16.	1719:26 UTC [0119:26 MYT]	The KL ACC radar Controller transferred MH370 to HCM ACC by instructing MH370 to contact Ho Chi Minh on the VHF radio frequency 120.9 MHz.	• Transfer of control was effected 3 minutes before the estimate for IGARI. • KL ACC passed to HCM ACC estimate for IGARI as 1722 UTC. • Transfer of control to HCM ACC was effected at 1719 UTC before MH370 was over IGARI. • There was no arrangement between KL ACC and HCM ACC for an "electronic handoff" or other methods to hand over the radar picture.
17.	1719:30 UTC [0119:30 MYT]	MH370 responded with: "*Good night Malaysian Three Seven Zero".*	Thereafter there was no further voice communication.

Table 2.2A - Chronology of ATC Events before the Disappearance of Flight MH370

2.2.3 Filed Flight Plan of MH370

```
KLA297 070444
FF WMKKZQZX WMKKZRZX
070441 WMKKYOYX
(FPL-MAS370-IS
-B772/H-SDFGHIJ3J5M1RWXY/LB1D1
-WMKK1635
-N0470F290 DCT PIBOS R208 IKUKO/M081F330 R208 IGARI M765
 BITOD/N0480F330 L637 TSN/N0480F350 W1 BMT W12 PCA G221
 BUNTA/N0480F370 A1 IKELA/N0480F370 P901 IDOSI/N0480F390 DCT CH
 DCT BEKOL/K0900S1160 A461 YIN/K0890S1130 A461 VYK
-ZBAA0534 ZBTJ ZBSJ
-PBN/A1B1C1D1L1O1S2 DOF/140307 REG/9MMRO EET/WSJC0032 VVTS0042

ZJSA0210 VHHK0233 ZGZU0304 ZHWH0356 ZPE0450 SEL/QRC RMK/ACASII
EQUIPPED)
```

JABATAN PENERBANGAN AWAM
PENGURUSAN TRAFIK UDARA
HQ
MALAYSIA
AIR TRAFFIC MANAGEMENT
DEPARTMENT OF CIVIL AVIATION

Source: DCA Malaysia

Figure 2.2A - Filed Flight Plan of MH370

1) Message Code of FPL of MH370 and Meaning

Message Code	Meaning
KLA297 070444	
KL	*KLIA message*
A	*Series*
297	*Sequence Number*
070444	*Date-time-group or the transmission time of the filed flight plan message at 070444UTC*

FF WMKKZQZX WMKKZRZX	
FF	*Priority Indicator for the message category*
WMKKZQZX	*8-letter addressee for Lumpur "Area Control Centre".*
WMKKZRZX	*8-letter addressee for Lumpur "Approach Radar Office".*

070441 WMKKYOYX	
070441	*Message Filling Time (in UTC)*
WMKKYOYX	*8-letter Message Originator for KLIA Aeronautical Information Office*

Field Type 3 - Message type, number and reference data	
(FPL	*Filed Flight Plan Message*
WMKKYOYX	*Message Originator Indicator i.e. KLIA Aeronautical Information Service Office.*

- Field Type 7- Aircraft Identification and SSR mode and code	
-MAS370	*Aircraft identification Malaysian 370*

-Field Type 8 - Flight rules and type of flight	
-I	*Instrument Flight Rules*
-S	*Status: - Scheduled Air Transport*

Field Type 9 - Number and type of aircraft and wake turbulence category	
-B772/H	*Boeing 777-200/wake turbulence category/Heavy*

Figure 2.2B - Message Code of Filed Flight Plan of MH370 and Meaning

cont…

1) Message Code of FPL of MH370 and Meaning (*cont...*)

Message Code	Meaning
Field Type 10 - Equipment and capabilities	
(a) **Radio communication, navigation and approach aid equipment and capabilities**	
-SDFGHIJ3J5M1RWXY/LB1D1	
-S	Equipped with: *Standard COM/NAV/approach aid equipment for the route is carried and serviceable. Standard equipment is considered to be VHF RTF, VOR and ILS.*
D	*DME*
F	*ADF*
G	*GNSS*
H	*HF RTF*
I	*Inertial Navigation*
J3	*CPDLC FANS 1/A VDL Mode 4*
J5	*CPDLC FANS 1/A SATCOM (INMARSAT)*
M1	*ATC RTF SATCOM (INMARSAT)*
R	*PBN approved.*
W	*RVSM approved*
X	*MNPS approved*
Y	*VHF with 8.33 kHz. channel spacing capability/*
(b) Surveillance equipment and capabilities	
L	*Transponder Mode S, including aircraft identification, pressure-altitude, extended squitter (ADS-B) and enhanced surveillance capability*
B1	*ADS-B with dedicated 1090 MHz ADS-B “out” capability*
D1	*ADS-C with FANS 1/A capabilities*
Field Type 13 - Departure aerodrome and time	
-WMKK1635	*-Departure aerodrome KLIA estimated off-block time 1635 UTC*

Figure 2.2B - Message Code of Filed Flight Plan of MH370 and Meaning

cont…

1) Message Code of FPL of MH370 and Meaning (*cont...*)

Message Code	Meaning
Field Type 15 – Route	
-N0470F290 DCT PIBOS R208 IKUKO/M081F330 R208 IGARI M765 BITOD/N0480F330 L637 TSN/N0480F350 W1 BMT W12 PCA G221 BUNTA/N0480F370 A1 IKELA/N0480F370 P901 IDOSI/N0480F390 DCT CH DCT BEKOL/K0900S1160 A461 YIN/K0890S1130 A461 VYK	
-airspeed 470 knots requested flight level 290 - the flight will proceed direct to waypoint PIBOS joining Airway R208 and to waypoint IKUKO, thence the airspeed will be Mach 0.81 flight level 330 on Airway R208 to waypoint IGARI joining Airway M765 thence to waypoint BITOD. Thence the airspeed will be 480 knots and flight level 330 on Airways L637 and proceed to TSN (Tansonnhat), thence the airspeed will be 480 knots and flight level 350. Thence on Airway W1 to BMT (Buon Ma Thout), thence Airway W12 to PCA (Phu Cat), thence on Airway G221 to waypoint BUNTA, thence airspeed will be 480 knots and flight level 370, thence proceed via Airway A1 to waypoint IKELA, thence airspeed will be 480 knots and flight level 370, thence via Airway P901 to waypoint ISODI, airspeed 480 knots and flight level 390. Thence track direct to CH (Cheung Chau), and direct to waypoint BEKOL. Thence the airspeed will be 900 kilometres per hour and level 11600 meters on Airway A461, thence to YIN (Yingde). Thence, the airspeed will be 890 kilometres per hour and level 11300 metres on Airway A461 to VYK (Dawangzhuang).	

Field Type 16 - Destination aerodrome and total estimated elapsed time, destination alternate aerodrome(s)
-ZBAA0534 ZBTJ ZBSJ
-Destination aerodrome ZBAA - Beijing Capital International Airport and total estimated elapsed time 5 hours and 34 minutes *Destination alternate aerodrome(s)* *ZBTJ -* Tianjin Binhai International Airport, and *ZBSJ -* Shijiazhuang Zhengding International Airport

Figure 2.2B - Message Code of Filed Flight Plan of MH370 and Meaning

cont...

1) Message Code of FPL of MH370 and Meaning (*cont..*)

Message Code	Meaning
Field Type 18 – Other information	
PBN/A1B1C1D1L1O1S2 DOF/140307 REG/9MMRO EET/WSJC0032 VVTS0042 ZJSA0210 VHHK0233 ZGZU0304 ZHWH0356 ZBPE0450 SEL/QRC RMK/ACASII EQUIPPED)	
PBN	*Performance Based Navigation/Indication of RNAV and or RNP capabilities.*
	RNAV Specifications
A1	*RNAV 10 (RNP 10)*
B1	*RNAV 5 all permitted sensors*
C1	*RNAV 2 all permitted sensors*
D1	*RNAV 1 all permitted sensors*
	RNP Specifications
L1	*RNP 4*
O1	*Basic RNP 1 all permitted sensors*
S2	*RNP APCH with BARCO-VNAV*
DOF/140307	*Date of flight/2014 March 7th*
REG/9MMRO	*Aircraft registration 9MMRO*
EET	FIR boundary designators and accumulated *estimated elapsed times from take-off to such FIR boundaries.* *Singapore FIR 32 minutes* *Ho Chi Minh FIR 42 minutes* *Sanya FIR 2 hours 10 minutes* *Hong Kong FIR 2 hours 33 minutes* *Guangzhou FIR 3 hours 4 minutes* *Wuhan FIR 3 hours 56 minutes* *Beijing FIR 4 hours 50 minutes*
SEL/QRC	*Selective Calling code/QRC*
RMK/ACAS II EQUIPPED)	*Equipped with ACAS II)*

Figure 2.2B - Message Code of Filed Flight Plan of MH370 and Meaning

2.2.4 Departure Message of MH370

Legal Recording ATS-Message

Type: **DEP** Priority: FF
Originator: WMFDYFYX Operator: 1A
Filing Time: 071642 Last Stordate: 14-03-07 16:42

Legal Recording Informations:
Date: 14-03-07 16:42:44 Action: Creation

ATS Message

(DEP-MAS370/A2157-WMKK1642-ZBAA-DOF/140307)

End of Report

Source : Dca Malaysia

Figure 2.2C - Departure Message of MH370

1) Message Code of Departure Message of MH370 and Meaning

Message Code	Meaning
(DEP	(Departure
-MAS370/A2157	-Aircraft identification MH370/Secondary Surveillance Radar Code A2157
-WMKK1642	-KLIA1642 (UTC)
-ZBAA	-destination aerodrome: Beijing/Capital
-DOF140307)	-Date of flight 2014March07)

Figure 2.2D - Message Code of Departure Message of MH370 and Meaning

2.2.5 Waypoints - Geographical Coordinates (LAT/LONG) of MH370 Filed Flight Plan

No.	WAYPOINT	LAT	LONG	AIRWAY
1.	PIBOS	N0320.5	E10203.1	R208
2.	IKUKO	N0545.2	E10313.4	R208
3.	IGARI	N0656.2	E10335.1	R208
4.	BITOD	N0715.4	E10407.1	M765
5.	TSN	N1049.0	E10638.7	L637
6.	BMT	N1240.0	E10807.4	W1
7.	PCA	N1357.4	E10902.5	W12
8.	BUNTA	N1650.0	E10923.7	G221
9.	IKELA	N1839.7	E11214.7	A1
10.	IDOSI	N1900.0	E11230.0	P901
11.	CH	N2213.2	E11401.8	DCT
12.	BEKOL	N2232.5	E11408.0	DCT
13.	YIN	N2411.4	E11324.9	A461
14.	VYK	N3911.7	E11634.3	A461

Table 2.2B - Waypoints of MH370 FPL

2.2.6 Analysis on FPL Message of MH370

1) The MH370 FPL had been filed in accordance with the Doc 4444 ATM/501, Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM).

2) However, there are two airways designated as A1/P901 within Hong Kong Flight Information Region (FIR) which required examination. Both airways (A1 and P901) are within the Hong Kong FIR, and have the same alignment and share the same waypoints. The waypoints are IKELA, IDOSI and CH (CHEUNG CHAU). The differences between the two airways are the lower limits and upper limits. The lower limit of A1 is 8,000 ft, and the upper limit is FL285 whereas the lower limit of P901 is FL285 and upper limit unlimited.

Note:

Refer to the following for details:

- *Figure 2.2E* (below) - *Route Segment of ATS Route A1 and Performance Based Navigation (PBN) Route P901;* and

- *Figure 2.2F* (below) - *Longitudinal Cross Section of ATS Route A1 and PBN Route P901*

3) It is observed that the fifth group of alphabet/number, written as ZPE0450, in line 13th of the FPL message of MH370 should read ZBPE0450. However, the missing alphabet B from the original text message does not invalidate the FPL.

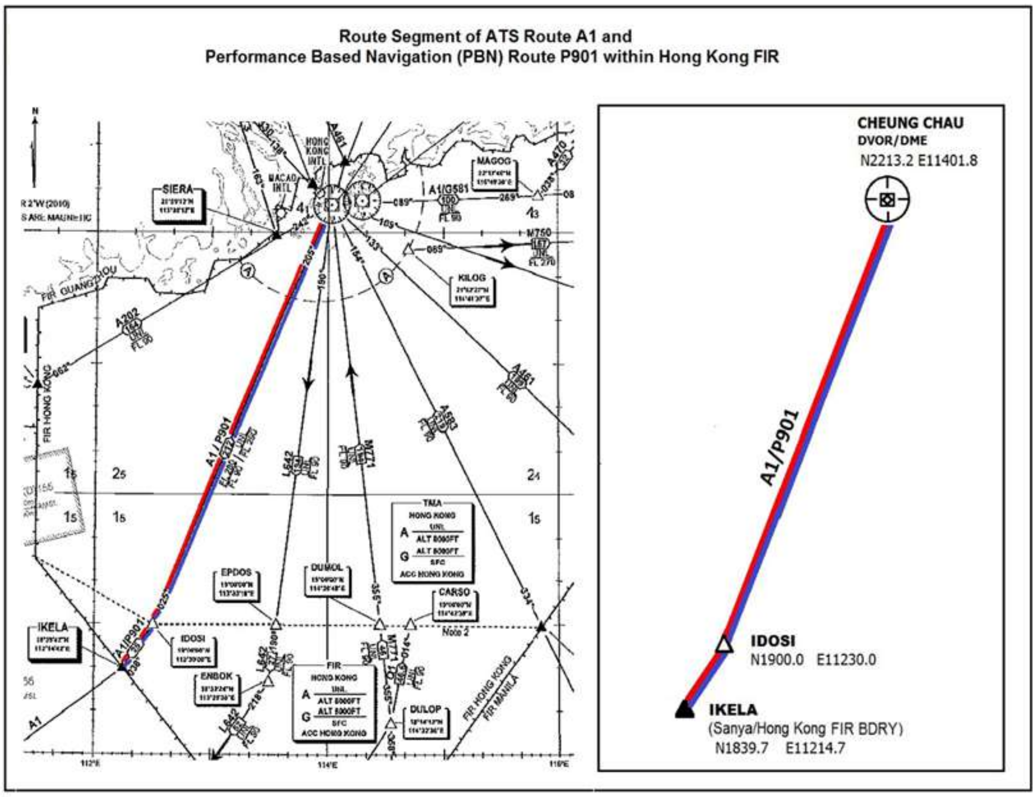


Figure 2.2E - Route Segment of ATS Route A1 and PBN Route P901

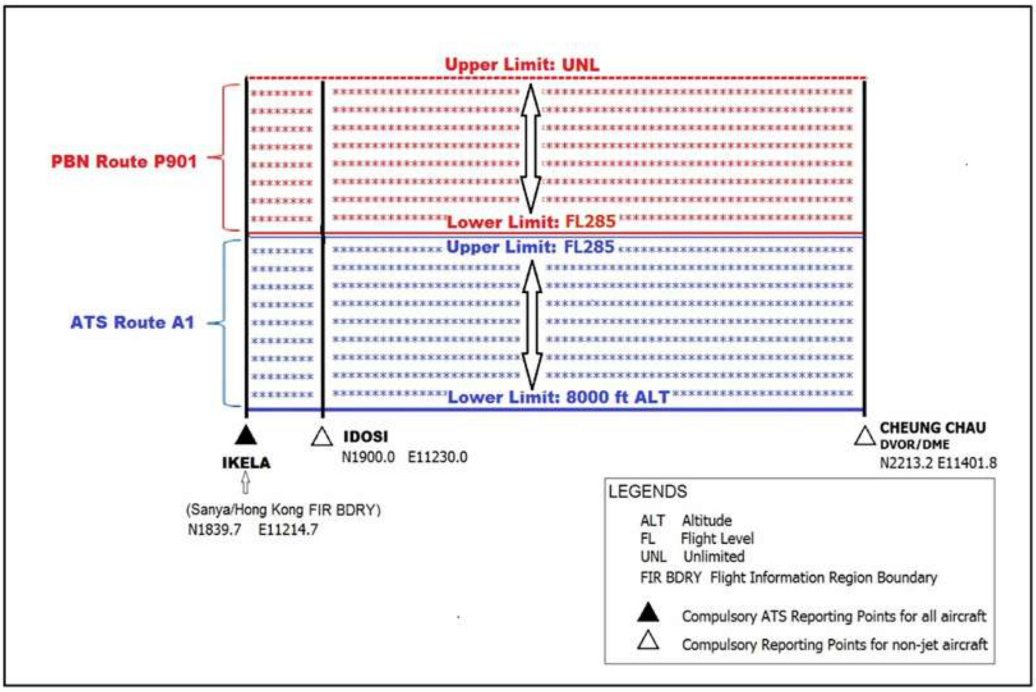


Figure 2.2F - Longitudinal Cross Section of ATS Route A1 and PBN Route P901

2.2.7 Chronology of ATC Events following the Disappearance of MH370 (*Table 2.2C*, below)

No.	Time	Event
1.	1720:31 UTC [0120:31 MYT]	Radar recording showed MH370 passed over waypoint IGARI.
2.	1720:36 UTC [0120:36 MYT]	Mode S radar symbol of MH370 dropped off from radar display.
3.	1721:13 UTC [0121:13 MYT]	3.2 nm after passing IGARI, SSR radar position symbol of MH370 dropped off from radar display. Two radar sources, from Viet Nam and Thailand respectively, captured the disappearance of the radar position symbol of MH370 vis-à-vis Bangkok radar target drop at 1721:13 UTC [0121:13 MYT] and Viet Nam's at 1720:59 UTC [0120:59 MYT].
4.	1739:03 UTC [0139:03 MYT]	HCM ACC queried KL ACC on whereabouts of MH370 and informed KL ACC that verbal contact with MH370 was not established and the radar target was last seen at waypoint BITOD. <u>Note</u>: MH370 did not arrive over waypoint BITOD (Refer to *Item 3* above).
5.	1741:22 UTC [0141:22 MYT]	HCM ACC enquired for information on MH370. KL ACC informed HCM ACC that after waypoint IGARI, MH370 did not return to Lumpur radar frequency.
6.	1741:23 UTC [0141:23 MYT]	KL ACC Radar Controller made a 'blind transmission'[30] to MH370.
7.	1746:47 UTC [0146:47 MYT]	HCM ACC queried on MH370 again, stating that radar contact was established at IGARI but there was no verbal contact. HCM ACC advised that the observed radar blip disappeared at waypoint BITOD. HCM ACC also stated that efforts had been made to establish communications by calling MH370 several times for more than twenty minutes.

Table 2.2C Chronology of ATC Events following the Disappearance of MH370

cont…

[30] Blind transmission - A transmission from one station to another station in circumstances where two-way communications cannot be established but where it is believed that the called station is able to receive the transmission.

2.2.7 Chronology of ATC Events following the Disappearance of MH370 (*Table 2.2C*, below)

No.	Time	Event
8.	1750:28 UTC [0150:28 MYT]	KL ACC queried HCM ACC if there was any contact with MH370. HCM ACC's reply was: "*Negative*".
9.	1757:49 UTC [0157:49 MYT]	HCM ACC informed that there was officially no contact with MH370 until this time. Attempts on many frequencies and aircraft in the vicinity received no response from MH370.
10.	1803:48 UTC [0203:48 MYT]	KL ACC queried HCM ACC on status of MH370. HCM ACC confirmed there was no radar contact at this time and no verbal communications was established. KL ACC relayed the information received from Malaysia Airlines Operations that aircraft was in Cambodian airspace.
11.	1807:47 UTC [0207:47 MYT]	HCM ACC queried for confirmation that MH370 was in Phnom Penh FIR as Phnom Penh did not have any information on MH370. KL ACC indicated it would check further with the supervisor.
12.	1812:15 UTC [0212:15 MYT]	KL ACC informed HCM ACC that there was no update on status of MH370.
13.	1815 UTC [0215 MYT]	Extract from Watch Supervisor Log Book (in written form only, no voice recording): *KL ATSC WS queried Malaysia Airlines Operations who informed that MH370 was able to exchange signals with the Flight Explorer.*
14.	1818:50 UTC [0218:50 MYT]	KL ACC queried if flight planned routing of MH370 was supposed to enter the Cambodian airspace. HCM ACC confirmed that planned route was only through the Vietnamese airspace. HCM ACC had checked and Cambodian had advised that it had no information on or contact with MH370. HCM ACC confirmed earlier information that radar contact was lost after BITOD and radio contact was never established.
15.	1833:59 UTC [0233:59 MYT]	KL ACC Radar Controller enquired with MAS Operations Despatch Centre (ODC) on communications status on MH370. Personnel was not sure if the message went through successfully. ODC informed that aircraft was still sending movement message indicating it was somewhere

Table 2.2C - Chronology of ATC Events following the Disappearance of MH370

cont...

2.2.7 Chronology of ATC Events following the Disappearance of MH370 (*Table 2.2C*, below)

No.	Time	Event
15. *cont..*	1833:59 UTC [0233:59 MYT]	in Viet Nam, and that its last position was at coordinates N14.90000 E109 15500 at 071833 UTC [080233 MYT].
16.	1834:56 UTC [0234:56 MYT]	HCM ACC queried on the status of MH370 and was advised that the Watch Supervisor was talking to the Company at this time.
17.	1854:28 UTC [0254:28 MYT]	Requested MH386, which was then in the HCM FIR, to try to establish contact with MH370 on emergency frequencies.
18.	1930 UTC [0330 MYT]	Extract from KL ACC Watch Supervisor ATS logbook: *MAS Operations Centre informed KL ACC that the flight tracker was based on flight projection and not reliable for aircraft positioning.*
19.	1930:03 UTC [0330:03 MYT]	KL ACC queried if HCM ACC had checked with next FIR HAINAN.
20.	1948:52 UTC [0348:52 MYT]	KL ACC queried if HCM ACC had checked with the SANYA FIR. HCM ACC informed KL ACC that there was no response until then.
21.	1956:13 UTC [0356:13 MYT]	KL ACC queried MAS Operations Centre for any latest information or contact with MH370.
22.	2025:22 UTC [0425:22 MYT]	HCM ACC Supervisor queried KL ACC on the last position that MH370 was in contact with KL ACC.
23.	2109:13 UTC [0509:13 MYT]	Singapore, on behalf of Hong Kong ACC enquired for information on MH370.
24.	2118:32 UTC [0518:32 MYT]	HCM ACC queried for information on MH370, KL ACC queried if any information had been received from Hong Kong or Beijing.
25.	2120:16 UTC [0520:16 MYT]	Capt. *xxxx* [*name redacted*] of MAS requested for information on MH370. He opined that based on known information,"*MH370 never left Malaysian airspace*."
26.	2130 UTC [0530 MYT]	Duty ATSC Watch Supervisor activated the Kuala Lumpur Aeronautical Rescue Coordination Centre (ARCC).

Table 2.2C - Chronology of ATC events following the disappearance of MH370

cont...

2.2.7 Chronology of ATC Events following the Disappearance of MH370 (*Table 2.2C*, below)

No.	Time	Event
27.	2214:13 UTC [0614:13 MYT]	KL ACC queried HCM ACC if SAR was activated.
28.	2232 UTC [0632 MYT]	KL ARCC issued a *DETRESFA* message.

Table 2.2C - Chronology of ATC Events following the Disappearance of MH370

2.2.8 ATS Operational Issues after Last Radio Communication with MH370 and subsequent ATS Activities/Actions

The following analysis are based on the ICAO Doc 4444 ATM/501, Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM), Annex 11 - Air Traffic Services, Aeronautical Information Publication, MATS and MATS Vol 2 Malaysia. Operation Letter of Agreement between DCA Malaysia and Viet Nam Air Traffic Management (effective 1 November 2011/, Letters of Operational Agreement Malaysia - Singapore dated August 1984 DCA/SAR01-84/Doc 04 (a).

They also include the Chronology of events following the disappearance of MH370, as tabulated above (*Table 2.2A)*, the Team had gathered these operational issues regarding activities/actions taken by KL ACC, HCM ACC and others as follows:

No.	Operational Issues
1.	Transfer of Control Point[31] at Waypoint IGARI
2.	Responsibilities of Accepting Air Traffic Control Service Unit on 'Establishment of Communications'
3.	Marking of MH370 Flight Progress Strips[32]
4.	Responsibilities of Air Traffic Controller
5.	Recognising Emergency Situations and ATC Actions

[31] Transfer of Control Point - A defined point located along the flight path of an aircraft at which the responsibility for providing air traffic control service to the aircraft is transferred from one control unit or control position to the next.

[32] Flight Progress Strip - It contains essential flight and control data and is the basic tool which enables Controllers to visualize the disposition of traffic within their area of responsibility including traffic arriving and departing an aerodrome, assess conflicts and control aircraft in a safe manner.

cont..

No.	Operational Issues
6.	Information to be passed to other Radar Stations - Civil and Military
7.	Provision of Alerting Service by an ATSU for flights operated through more than one FIR and ATC actions
8.	Actions taken by Duty ATSC Watch Supervisor
9.	Flight-following System of Malaysia Airlines
10.	Communications Exchanges between KL ACC and HCM ACC, and KL ACC and Malaysia Airlines Operations Centre on MH370
11.	Delegation of Airspace from Singapore ACC to KL ACC
12.	ATC Actions on Strayed/Unidentified Aircraft (Primary Radar Target) within Area of Responsibility
13.	KL ATSC Duty Shift System for Air Traffic Controllers
14.	Roles played by the ATSC Duty Watch Supervisor
15.	Activation of Aeronautical Rescue Coordination Centre
16.	Playback of Radar and Radio Telephony Recordings by Duty ATSC Watch Supervisor
17.	Entries in Air Traffic Services Logbooks of ATSC Duty Watch Supervisor and Sector 3 Controller Working Position
18.	Distress Message
19.	Issues with the Manual of Air Traffic Services

1) Analysis of ATS Operational Issues after Last Radio Communication with MH370 and subsequent Activities/Actions taken

a) Transfer of Control Point at Waypoint IGARI

i) The MH370 flight from Kuala Lumpur to Beijing was planned on ATS/RNAV Routes R208 IGARI M765 BITOD L637 TSN…ZBAA. About one and a half minutes after MH370 took off at 1642 [0042 MYT], KL ACC conveyed to HCM ACC via the direct land line the estimate for waypoint IGARI as 1722 UTC [0122MYT], and requested Flight Level three five zero and Squawk two one five seven. HCM ACC acknowledged: "*two one five seven, three five zero is approved, one seven two two*".

ii) The Transfer of Control Point (TCP) for flights on route R208 IGARI M765 BITOD L637 TSN…ZBAA is IGARI. Aircraft operating on this route shall be transferred by KL ACC to HCM ACC when the Radar Controller observes on the radar display that the aircraft is over IGARI or when the aircraft reports over IGARI.

iii) The transfer of control by KL ACC to HCM ACC is by way of instructing the aircraft concerned on the control VHF (very high frequency) radio frequency 132.5 MHz to contact HCM ACC on VHF radio frequency 120.9 MHz. The ATS infrastructure in KL ACC was not equipped to perform an "electronic handoff" of aircraft or other method to hand over the radar picture to HCM ACC.

References:

MATS Vol. 2, Part 2 KL ATSC - Coordination, para. 3.5.8, page 2-3-53 Coordination between Sector 5 Position and HCM ACC dated 15 March 2013 (*Table 2.2E)* as shown below.

The LOA (*Appendix 1.1A*) between DCA Malaysia and Vietnam Air Traffic Management dated 18 July 2001 and effective on 01 November 2001, para Transfer of Control Point *(Table 2.2D* [below]*),* page 7, as below:

Co-ordination Procedures

Transfer of Control Point

Route	TCP
M765	IGARI (065612N 1033512E)
N891	
R208 / M765	

Table 2.2D - Coordination Procedures

Manual Of Air Traffic Services Volume 2 | Part 2 KL ATSC – Coordination

3.5.8 Coordination Between Sector 5 and Ho Chi Minh ACC

Sector 5's Actions				
Destination	Route	Pass EST for	Transfer To	Transfer At
Entering Ho Chi Minh FIR	R208 (E)	IGARI	Ho Chi Minh Sector 3	IGARI
	M765 (E)			
	N891 (N)			

Ho Chi Minh ACC's Actions				
Destination	Route	Pass EST for	Transfer To	Transfer At
Entering Kuala Lumpur FIR/AOR	M765 (W)	IGARI	Lumpur Sector 5	IGARI
	N891 (S)			

3.5.9 Coordination Between Sector 5 and Singapore ACC

Sector 5's Actions				
Destination	Route	Pass EST for	Transfer To	Transfer At
Entering Singapore FIR	N891 (S)	IGARI	Singapore Sector 3	IKUMI
	M904 (S)	TIDAR		A/Beam IKUMI

Singapore ACC's Actions				
Destination	Route	Pass EST for	Transfer To	Transfer At
Entering Kuala Lumpur FIR	N891 (N) N891 (S)	IGARI	Lumpur Sector 5	IKUMI
	M904 (N)	A/Beam IKUMI		A/Beam IKUMI

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Table 2.2E - Coordination between Sector 5 and Ho Chi Minh ACC

(1) The Transfer of Control Point as stated in the Doc 4444 Chapter 10 - Coordination, paragraph, 10.1.2.2, page 10-3 dated 10/11/16 is as follows:

10.1.2.2.1 The responsibility for the control of an aircraft shall be transferred from the ATC unit to the next unit at the time of crossing the common control area boundary as determined by the unit having control of the aircraft or at such other point or time as has been agreed between the two units.

10.1.2.2.2 Where specified in letters of agreement between the ATC units concerned, and when transferring an aircraft, the transferring unit shall notify the accepting unit that the aircraft is in position to be transferred, and specify that the responsibility for control should be assumed by the accepting unit forthwith at the time of crossing the control boundary or other transfer control point specified in letters of agreement between the ATC units or at such other point or time coordinated between the two units.

10.1.2.2.3 If the transfer of control time or point is other than forthwith, the accepting ATC unit shall not alter the clearance of the aircraft prior to the agreed transfer of control time or point without the approval of the transferring unit.

10.1.2.2.4 If transfer of communication is used to transfer an aircraft to a receiving ATC unit, responsibility for control shall not be assumed until the time of crossing the control area boundary or other transfer of control point specified in letters of agreement between the ATC units.

(2) KL ACC transferred MH370 to HCM ACC by instructing MH370 to contact Ho Chi Minh on the VHF radio frequency 120.9 MHz at 1719:26 UTC [0119:26 MYT].

(3) MATS Vol. 2, Part 2 KL ATSC and Operational Letter of Agreement between DCA Malaysia and Viet Nam Air

Traffic Management do not have provision for KL ACC to effect transfer of communication of an aircraft to HCM ACC. It is noted that MH370 was transferred to HCM ACC three minutes before the Transfer of Control Point.

(4) The recorded landline communications between KL ACC and HCM ACC suggested that there were confusions on the position of MH370. This was evident when HCM ACC requested KL ACC for information on MH370 at 1739:06 UTC [0139:06].

(5) The following timings were based on recordings vis-à-vis landline/radiotelephony communications and radar recording:

(a) 1643 UTC - KL ACC passed MH370's estimated time over IGARI at 1722 UTC to Ho Chi Minh ACC.

(b) 1719:26 UTC - MH370 was instructed by KL ACC to contact Ho Chi Minh ACC.

(c) 1719:30 UTC - MH370 acknowledged.

(d) 1720:31 UTC - MH370 passed over IGARI.

From the above timings, it is evident that there was a 3-minute lapse from the time MH370 was instructed to HCM ACC and the original estimate.[33]

(6) Radiotelephony Readback

(a) Readback Messages

MATS Part 10 - COM, page 10-3-3 para 3.4.4 states that:

Pilots are required to read back in full messages containing any of the following:

a) Level instructions;

b) Heading instructions;

c) Speed instructions;

d) Airways or route clearances;

[33] See *Table 2.2A* – Chronology of ATC Events before the Disappearance of Flight MH370 for detailed timeline plot.

e) Runway in use;

f) Clearance to enter, land on, take-off, backtrack, cross or hold short of an active runway;

g) SSR operating instructions;

h) Altimeter settings;

i) Frequency Changes

(b) Readback on Frequency Changes

Annex 11 - Air Traffic Services, page 3-7 para 3.7.3 states:

Readback of clearances and safety-related information.

3.7.3.1 The flight crew shall read back to the Air Traffic Controller safety-related parts of ATC clearances and instructions which are transmitted by voice. The following items shall always be read back:

a) ATC route clearances;

b) clearances and instructions to enter, land on, take-off from, hold short of, cross and backtrack on any runway; and

c) runway-in use, altimeter settings, SSR codes, level instructions, heading and speed instructions and, whether issued by the Controller or contained in ATIS broadcasts, transition levels.

3.7.3.1.1 Other clearances or instructions, including conditional clearances, shall be read back or acknowledged in a manner to clearly indicate that they have been understood and will be complied with.

(c) Doc 4444 Air Traffic Management (PANS-ATM) Pages 4-8 para 4.5.7.5 states that:

4.5.7.5.1 The flight crew shall read back to the Air Traffic Controller safety-related parts of ATC clearances and instructions which are *transmitted by voice. The following items shall always be read back:*

a) ATC route clearances;

b) clearances and instructions to enter, land on, take-off from, hold short of, cross and backtrack on any runway; and

c) runway-in-use, altimeter settings, SSR codes, level instructions, heading and speed instructions and, whether issued by the Controller or contained in automatic terminal information service (ATIS) broadcasts, transition levels.

4*.5.7.5.1.1 Other clearances or instructions, including conditional clearances, shall be read back or acknowledged in a manner to clearly indicate that they have been understood and will be complied with.*

(d) Pilot's Readback on Frequency Changes

MATS clearly stipulates that pilots are required to read back radio frequency changes. Similarly, ICAO Annex 11 and ICAO Doc 4444 also stipulate that:

"other clearances or instructions shall be read back or acknowledged in a manner to clearly indicate that they have been understood and will be complied with".

At 1719:26 UTC KL ACC had instructed MH370 to contact Ho Chi Minh on radio frequency one two zero decimal nine (120.9). MH370 was therefore required to read back the frequency change as an acknowledgment and thereby had complied with the instruction. There was no readback from MH370.

There were altogether five instances where MH370 had to change radio frequencies when transferred from an ATC unit to another. They are as follows:

- From Airways Clearance Delivery to Lumpur Ground (*Note 1*, below);

- From Lumpur Ground to Lumpur Tower (*Note 2* below);
- From Lumpur Tower to Lumpur Approach (*Note 3* below);
- From Lumpur Approach to Lumpur Radar (Sector 3+5) [*Note 4* below]; and
- From Lumpur Radar (Sector 3+5) to Ho Chi Minh (*Note 5*, below).

Note 1

When Airways Clearance Delivery transferred MH370 to Lumpur Ground, the radio frequency of Lumpur Ground was not mentioned by the ATC. MH370 responded by transmitting *“Good day sir.”*

Note 2

When Lumpur Ground transferred MH370 to Lumpur Tower, the Lumpur Tower radio frequency was transmitted by the Controller even though it was unintelligible in the RT recording, MH370 read back the radio frequency, *“One one eight eight Malaysian Three Seven Zero thank you.”*

Note 3

When Lumpur Tower transferred MH370 to Lumpur Approach Control, ATC transmitted the take-off clearance, no radio frequency was included in the take-off clearance and the pilot read back the take-off clearance, *“Three Two Right clear for take-off Malaysian Three Seven Zero thank you bye.“*

Note 4

When Lumpur Approach Control transferred MH370 to Lumpur Radar (Sector 3+5), the Sector 3+5 radio frequency was transmitted by Lumpur Approach Control and MH370 read back the radio frequency, *“Night one three two six Malaysian err… Three Seven Zero”.*

Note 5

When Lumpur Radar (Sector 3+5) transferred MH370 to Ho Chi Minh, the radio frequency of Ho Chi Minh was transmitted by Lumpur Radar (Sector 3+5), MH370 responded with *“Good night Malaysian Three Seven Zero”,* the radio frequency of Ho Chi Minh was not read back by MH370.

There were two instances when radio frequency was not included in the ATC instructions and three instances when radio frequency was included in the ATC instructions, MH370 had read back the radio frequency on two of the instances but did not on the last radio transmission. The Team could not conclude any reason for the absence of the read-back at this stage of the flight but noted that it was not consistent with the previous frequency changes.

(e) Maintaining FL350 Transmitted Twice

At 1701:17 UTC [0101:17 MYT] MH370 made a radio transmission: “*Maintaining flight level three five zero three seven zero”* and again at 1707:56 UTC [0107:56 MYT].

The MAS Standard Operating Procedures (SOPs) for flight crew dictated that the PIC and the FO would have to be on-seat during the following phrases of flight:

- Take-off;
- Climbing and descending; and
- Approach and landing.

However, one of the flight crew could leave the cockpit for a break once the aircraft had maintained the assigned cruising level.

The voice recognition process (*para 1.5.11*) has established that the PIC made the radio transmission of *maintaining flight level three five zero* at 1701:17 UTC [0101:17 MYT] and again at 1707:56 UTC [0107:56 MYT].

The interval between the first and second radio transmission was 6 minutes and 39 seconds.

Repetition of radiotelephony communications happens occasionally. While the Team could not determine the reason for the additional transmission at this stage of the flight, it was noted that it was anomalous at this time.

b) Responsibilities of Accepting Air Traffic Control Service Unit on Establishment of Communications

i) The 3rd paragraph of page 11 of the LOA between DCA Malaysia and Viet Nam Air Traffic Management (*Appendix 1.1A*), titled Establishment of Communication states that:

a. "*The accepting unit shall notify the transferring unit if two-way communication is not established within five (5) minutes of the estimated time for the TCP".*

ii) Since HCM ACC had earlier received from KL ACC MH370's estimate (as 1722 UTC [0122 MYT] for IGARI and also had not been able to establish two-way communication with the aircraft, HC ACC should have notified KL ACC by 1727 UTC [0127 MYT], i.e. 1722 UTC [0127 MYT] plus 5 minutes. Instead HCM only notified KL ACC at 1739 UTC [0139].

iii) The direct line coordination between KL ATCC Sector 3+5 Planner states that, at 1747:09 UTC [0147 MYT]. HCM ATCC informed KL ATCC that: "*we call him many times until na…more than 20 minutes."* This shows that HCM ATCC had commenced communication search for MH370 FROM 1727 UTC [0127 MYT].

iv) At 1757:51 [0157:51 MYT], HCM ATCC again informed KL ATCC: "*Yes sir, we officially no contact from Malaysian Three Seven Zero until now and we try on many frequencies and all the aircraft calling, no response from Malaysian Three Seven Zero."*

v) The 12 minutes lapse on the part of HCM ACC to notify KL ATCC could have come about by their actions to carry out communication search and thereby had resulted in their failure to notify KL ATCC by 1727 UTC [0127 MYT.

Note

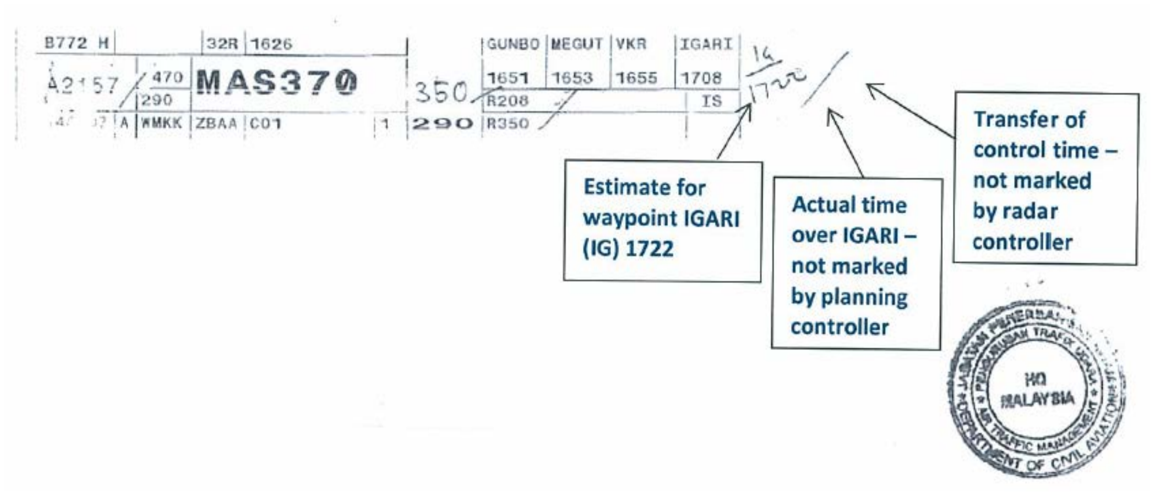
The 12 minutes interval is derived from the timings of the two-way radio communication recording between HCM ACC and KL ACC *(para 2.2.9 para. b) i)* above for details.

c) Marking on MH370 Flight Progress Strip

i) Two markings have been left out on the flight progress strip (FPS), *Figure 2.2G,* (below) of MH370:

(1) The actual time (1721) when MH370 passed over IGARI - FPS' Estimate IG (abbreviation for IGARI) 1722, and

(2) The transfer of control time (1719) on the FPS.



Source: DCA Malaysia

Figure 2.2G - Flight Progress Strip on MH370 from KL ACC

(3) Strip Marking on Flight Progress Strips

MATS Vol 2, Part 2 KL ATSC - General, page 2-1-8 para 1.4 dated 15 March 2009 and page 2-1-9 dated 15 March 2009 shows example of how the flight progress strip of a flight is marked.

Refer (below): *Figure 2.2H - Strip Marking on Flight Progress Strips generated by FDPS,* and *Figure 2.2I - Example on how the PLN strip will appear and Example on how the EXE strip will appear.*

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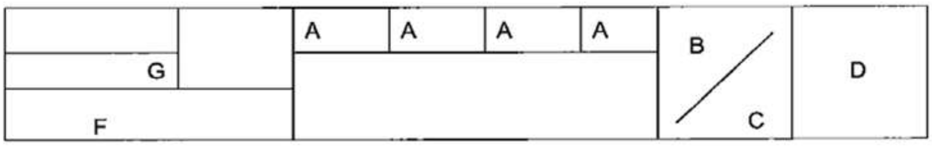
1.4 STRIP MARKING ON FLIGHT PROGRESS STRIPS (FPS) GENERATED BY FDPS



BOX	PLAN	EXE
A		Estimated time over fix
B	Estimated time over fix	Miscellaneous
C	Actual time over fix	
D	Flight level	
E	ATC restriction / requested level / lowest	
F	Level approved	
G	SSR code	

Note : The estimates in Box A are not necessarily accurate. PLN shall use Box B to write down the estimated time over a single fix whereas. EXE will write down the estimated time over the multiple fixes in Boxes A. The actual time over a fix will be reflected in PLN's Box C.

Example of a FPS generated by the FDPS

MAS 72	PE 000	PULIP	VKB	BASIR	IGARI		
	140	0056	0116	0121	0124		
1 / B747 / H		WMKK	G466/M765		VHHH		
IS N503 0045	330	PULIP 32R					

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Figure 2.2H - Strip Marking on Flight Progress Strips generated by FDPS

MATS Vol 2, Part 2 KL ATSC - General, page 2-10-9 para contd. 1.4 dated 15 March 2009:

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Example of how the PLN strip will appear

MAS 72	AR	**GUNBO**	**VKR**	**IKUKO**	**IGARI**	IGARI	
	140	**0107**	**0111**	**0115**	**0124**	0126 27	330
1/B747/H A2134		WMKK		R208	VHHH	27	~~270~~
IS N503 0045	270	RL330MAS84P10					

Box	Meaning
B	MAS 72 estimates IGARI 0126 and revised to 0127
C	MAS 72 passed IGARI 0127
D	MAS 72 was assigned FL270 initially and recleared FL330
E	Restriction for MAS 72 to depart 10 minutes after MAS 84
F	FL 270 has been approved by ACD
G	Transponder Code A 2134 was assigned by the FDP

Example of how the EXE strip will appear

MAS 73	AR	**IGARI**	**IKUKO**	**GUNBO**	**PIBOS**	IGARI	380
	150	**1010**	**1018**	**1026**	**1037**	1010	
1/B747/H A3003		VHHH	R208		WMKK		
IS N503 0045	380				PIBOS 32R	10	150

Box	Meaning
A	MAS 73 estimates IGARI 1010 IKUKO 1018 GUNBO 1026 PIBOS1037
B	MAS 73 passed over IGARI 1010
D	MAS 73 is at FL 380 and has been cleared down to FL 150

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Figure 2.2I - Example on how the PLN strip will appear and Example on how the EXE strip will appear

Since the two recordings on the Flight Progress Strip for MH370 were not marked by the Air Traffic Controllers (Planner and Radar) KL ACC did not have the record of the time of the last radio contact and the actual time of MH370 passing over waypoint IGARI.

d) Responsibilities of Air Traffic Controllers

i) MATS Vol. 1, Part 1 - ADMIN, para 1.2.2, page 1-1-4, which states as below:

Air Traffic Controller is responsible:

- *for maintaining a continuous watch on their assigned communications channels or radar displays.* [Refer para. v) below].

ii) In interviews conducted with the Air Traffic Control Officer (ATCO) who was on duty on the night of the disappearance of MH370, the Sector 3+5 Radar Controller stated that he did not continuously monitor the progress of MH370 because he had to shift his focus to another area, viz. VPK[34] (approximately 214 nm south-southwest of IGARI), as there were four other flights over that area that required his attention.

iii) The radiotelephony transcripts of this sector confirmed that there were other four other flights - one at 1723 UTC [0123 MYT] proceeding to VPK and contacting Lumpur Radar and three others at 1726 UTC [0126 MYT], 1742 UTC [0142 MYT] and 1746 UTC [0146 MYT] respectively.

iv) MH370 was operating in the Sector 3+5 Area of Responsibility (AOR) when the Radar Controller transferred the aircraft to HCM ACC. As he had not been monitoring the progress of the flight of MH370, the Sector 3+5 Radar Controller was not aware when MH370 passed the TCP IGARI, and when the MH370 radar display symbol started to "coast" and dropped from the radar display.

[34] VPK - Pekan DVOR/DME coordinates 032259N 1032524E.

v) Notwithstanding the fact that he had to shift his focus to another area within his AOR, the Radar Controller was still required to monitor the progress of MH370. The responsibility of the Sector 3+5 Radar Controller for MH370 did not end with the transfer of control to HCM ACC. The process of transfer of control is only with regard to Air Traffic Control Service. Therefore, the Sector 3+5 Radar Controller was still responsible for the provision of alerting service to MH370 as it was still operating within his AOR. The responsibility of the provision of alerting service would end when MH370 had a two-way radio communication with HCM ACC.

vi) The Radar Controller was not aware when MH370 radar position symbol dropped off from the radar display.

e) Recognising Emergency Situations and Air Traffic Control Actions

i) Upon receipt of the query from HCM ACC at 1739 UTC [0139 MYT] that HCM ACC had not been able to establish two-way radio communications with MH370, the Lumpur Sector 3+5 Radar Controller should have realised that MH370 could be experiencing an emergency situation. This was especially so after he had tried to establish radio communication with MH370 by making a ‘blind transmission’ on the VHF radio frequency 132.5 MHz at 1741:23 UTC [0141:23 MYT], without success.

ii) Under such circumstances and upon notification from HCM ACC that there were no two-way radio communications with the aircraft and/or subsequent inquiries to other sources had failed to reveal any news of the aircraft, the Sector 3+5 Radar Controller should have immediately notified the ATSC Duty Watch Supervisor and ARCC that an *Uncertainty Phase* had existed. By then, the Radar Controller should have commenced full overdue action (not later than 30 minutes after the declaration of an *Uncertainty Phase*), i.e. notify the KL ARCC that an *Alert Phase* existed.

iii) Manual of Air Traffic Services, Part 9 - Emergencies, page 9-6-5, para. 6.7.2 dated 15/3/2009 states:

If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegate to the Kuala Lumpur and Kota Kinabalu ATSCs and the position of the aircraft is in doubt, the responsibility for co-ordinating such service shall normally rest with the ATSC of the respective FIRs:

within which the aircraft was flying at the time of last air-ground radio contact.

<u>Reference</u>

Manual of Air Traffic Services, Part 9 - Emergencies, page 9-6-5, para. 6.7.2 dated 15/3/2009 No. 1 states:

If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegate to the Kuala Lumpur and Kota Kinabalu ATSCs and the position of the aircraft is in doubt, the responsibility for co-ordinating such service shall normally rest with the ATSC of the respective FIRs:

- *within which the aircraft was flying at the time of last air-ground radio contact;*
- *that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;*
- *within which the aircraft's intermediate stop or final destination point is located:*

  1) *if the aircraft was not equipped with suitable two-way radio communication, or*
  2) *was not under obligations to transmit position reports.*

and

ICAO Doc 4444 ATM/501 Procedures for Air Navigation - Air Traffic Management (PANS-ATM), page 9-6, para 9.2.2.2, dated 22/11/07 states:

When alerting services is required in respect of a flight operated through more than one FIR or control area, and when the position of the aircraft is in doubt, responsibility for coordinating such service shall rest with the ATS unit of the FIR or control area within which the aircraft was flying at the time of last air-ground radio contact:

a) that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;

b) within which the aircraft's intermediate stop or final destination point is located:

1) if the aircraft was not equipped with suitable two-way radio communication, or

2) was not under obligations to transmit position reports.

The responsibility for the provision of alerting service for MH370 therefore rested on KL ACC.

iv) Following the *Alert Phase*, the *Distress Phase* should be declared by the Radar Controller after further unsuccessful attempts to establish communication with the aircraft and more widespread unsuccessful inquiries pointed to the probability that the aircraft was in distress.

References

(1) MATS, PART 9 - EMERGENCIES, para 1.3.1 a) and b) page 9-1-2 Ver.01 stipulates that:

Controller may suspect that an aircraft is experiencing an emergency situation or that an emergency situation exists if one of the following situations becomes apparent:

a) *when radio contact is not established at the time it is expected to be established;*

b) *radio or radar contact is lost;*

c) *pilot reports a malfunction or unusual behaviour of person(s) on board;*

d) *pilot reports of unlawful interference;*

e) *aircraft is observed or reported to be behaving erratically;*

f) *aircraft is overdue at an aerodrome; and*

g) *an ELT signal is heard or is reported.*

(2) MATS PART 9 - EMERGENCIES, SECTION 2 OVERDUE AIRCRAFT, para. 2.1.1, page 9-2-1, No.1, dated 15/03/2009 stipulates that:

ATC action with respect to an aircraft that is overdue should not be considered in isolation, and the emergency actions described in other sections, in particular radio failure procedures, should be applied if they are appropriate. For example, if a radio-equipped aircraft fails to make an expected report, continuous attempts should be made to re-establish communications while at the same time initiating overdue action.

(3) MATS PART 9 - EMERGENCIES, SECTION 2 OVERDUE AIRCRAFT, para. 2.1.3, page 9-2-1, also stipulates that:

Overdue action must be commenced not later than the times stipulated in the procedure herein. Controllers may at their own discretion consider initiating actions before the times stated. The following consideration will assist Controllers in making a decision:

Route - The need for prompt action if the route is over sparsely populated area, mountainous country, and long stretches of water.

(4) MATS PART 9 - EMERGENCIES, Table 9-2-2, page 9-2-3 OVERDUE ACTION - RADIO EQUIPPED AIRCRAFT

ATSC Procedures

Preliminary action

When an aircraft fails to make a position report when it is expected, commence action not later than the ETA for the reporting point plus 3 minutes:

- *Confirm ATD and time of last contact with preceding ATS unit if appropriate;*
- *Request information from other ATS units and likely aerodromes;*
- *Notify the RCC that the Uncertainty Phase exists; and*
- *Ensure that RQS message is sent.*

Full overdue Action

Commence full overdue action not later than 30 minutes after the declaration of the Uncertainty Phase or when advised by the Aerodrome that the aircraft is fully overdue:

- *Notify the RCC that the Alert Phase exists;*
- *Notify the RCC that the Distress Phase exists if:*

i) 1 hour has elapsed beyond the last ETA for the destination; or

ii) the fuel is considered exhausted; or

iii) 1 hour has elapsed since the declaration of the Uncertainty Phase.

(5) ATC actions on the declaration of emergency phases should be taken as shown below:

MATS PART 9 - EMERGENCIES, page 9-6-2 – para

9-6-4, para 6.4 and Annex 11, page 5-1, para 5.2.1 states:

a) *Uncertainty Phase when*:

1) *no communication has been received from an aircraft within a period of thirty minutes after the time a communication should have been received, or from the time an unsuccessful attempt to establish communication with such aircraft was first made, whichever is the earlier, or when an aircraft fails to arrive within thirty minutes of the estimated time of arrival last notified to or estimated by air traffic units, whichever is the earlier, except when no doubt exits as to the safety of the aircraft and its occupants.*

b) Alert Phase when:

1) following the uncertainty phase, subsequent attempts to establish communication with the aircraft or inquiries to other relevant sources have failed to reveal any news of the aircraft, or when

2) an aircraft has been cleared to land and fails to land within five minutes of the estimated time of landing and communication has not been re-established with the aircraft, or when

3) information has been received which indicates that the operating efficiency of the aircraft has been impaired, but not to the extent that a forced landing is likely, except when evidence exists that would allay apprehension as to the safety of the aircraft and its occupants, or when

4) an aircraft is known or believed to be the subject of unlawful interference.

c) Distress Phase when:

1) following the alert phase, further unsuccessful attempts to establish communication with the aircraft and more widespread unsuccessful inquiries point to the probability that the aircraft is in distress, or when

2) the fuel on board is considered to be exhausted, or to be insufficient to enable the aircraft to reach safety, or when

3) information is received which indicate that the operating efficiency of the aircraft has been impaired to the extent that a forced landing is likely, or when

4) information is received or it is reasonably certain that the aircraft is about to make or has made a forced landing except when there is reasonable certainty that the aircraft and its occupants are not threatened by grave and imminent danger and do not require immediate assistance.

f) Information to be passed to other Radar Units - Civil and Military

The Sector 3+5 Radar Controller did not inform other radar units, civil and military, of the circumstances surrounding MH370. MATS PART 9 - EMERGENCIES, para 6.2.3, page 9-6-2, stipulates that:

If Controllers have reason to believe that an aircraft is lost, overdue or experiencing a communication failure, they shall:

a) inform appropriate radar units (civil and military) of the circumstances.

b) request the units to watch out for emergency SSR code display or the triangular radio failure pattern.

c) notify these units when their services is no longer required.

g) Provision of Alerting Service for Flight operating through more than one FIRs and ATC Actions

MH370 was operating within the Singapore FIR, in that portion of the airspace which has been delegated to Malaysia (refer to *Figure 2.2K - Singapore Airspace delegated to Malaysia*) for the provision of air traffic services when the last air-ground radio contact was made at 1719 UTC [0119 MYT]. As such, KL ACC should be responsible for the alerting service which would mean that KL ACC would have to declare the Distress Phase at 1827 UTC [0227 MYT] when HCM ACC informed that there had been no two-way radio communications with MH370.

Reference

Manual of Air Traffic Services, Part 9 - Emergencies, page 9-6-5, para. 6.7.2 dated 15/3/2009 No. 1 states:

If alerting service is required for an aircraft that is flight planned to operate through more than one FIR including the airspace delegate to the Kuala Lumpur and Kota Kinabalu ATSCs and the position of the aircraft is in doubt, the responsibility for co-ordinating such service shall normally rest with the ATSC of the respective FIRs:

- *within which the aircraft was flying at the time of last air-ground radio contact;*
- *that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;*
- *within which the aircraft's intermediate stop or final destination point is located:*

  3) if the aircraft was not equipped with suitable two-way radio communication, or

  4) was not under obligations to transmit position reports.

and

ICAO Doc 4444 ATM/501 Procedures for Air Navigation - Air Traffic Management (PANS-ATM), page 9-6, para 9.2.2.2, dated 22/11/07 states:

When alerting services is required in respect of a flight operated through more than one FIR or control area, and when the position of the aircraft is in doubt, responsibility for coordinating such service shall rest with the ATS unit of the FIR or control area within which the aircraft was flying at the time of last air-ground radio contact:

c) that the aircraft was about to enter when last air-ground contact was established at or close to the boundary of two FIRs or control areas;

d) within which the aircraft's intermediate stop or final destination point is located:

3) if the aircraft was not equipped with suitable two-way radio communication, or

4) was not under obligations to transmit position reports.

The responsibility for the provision of alerting service for MH370 therefore rested on KL ACC.

h) Actions taken by Air Traffic Service Centre Duty Watch Supervisor

In interviews conducted with the Duty Air Traffic Controllers on that night, the Team recorded the following:

i) At about 1800 UTC [0200 MYT], the Sector 3+5 Radar Controller had instructed a junior Controller to inform the ATSC Duty Watch Supervisor - who was then in the rest area[35] - on HCM ACC's query on the status of MH370;

ii) The ATSC Duty Watch Supervisor stated that he subsequently left the rest area and returned to the ATSC. He contacted MAS Operations Despatch Centre (ODC) by telephone (albeit not tape-recorded) to inform that HCM ACC had not been able to establish radio and radar contact with MH370. In response ODC informed that the Flight-following System (FFS) or *Flight Explorer* of MAS showed that: "*aircraft in Cambodian airspace*" and added that he

[35] Rest area - It is located in the same building adjacent to ATSC and is furnished with 3 x double-decker beds for the night shift Controllers to rest/sleep during break in between shift.

(ODC) would try to use the ACARS to contact MH370 and also to request the aircraft to contact HCM ACC. The ATSC Duty Watch Supervisor stated that he was satisfied with the information that MH370 was still flying and therefore did not take any further actions.

iii) The junior Controller (who had earlier informed the ATSC Duty Watch Supervisor in the rest area) stated that the ATSC Duty Watch Supervisor then returned to the rest area at around 1830 UTC [0230 MYT] until about 2130 UTC [0530 MYT].

iv) At 2130 UTC [0530 MYT], the ATSC Duty Watch Supervisor initiated the alerting action by instructing the SAR-trained Controller to activate the KL ARCC.

v) At 2232 UTC [0632 MYT], the *DETRESFA* message was disseminated

i) Flight-Following System of Malaysia Airlines

(1) In interviews conducted with the MAS duty personnel in charge of the FFS on the night of 07 March 2014, he was not able to explain clearly on the operations of the system due to "*lack of training*". The Team was also informed that all the personnel in this unit were not adequately trained to operate this system. The MAS personnel also informed the Team that the FFS could not track aircraft on a real-time basis and that the position information was computer-projected, based on the flight plan of aircraft. He added that the status of an aircraft position would only be updated every thirty (30) minutes. He admitted that he had informed KL ACC that MH370 was in Cambodian airspace as during: *"…that point in time, I did not notice that the position was actually projected movement and not actual"*.

Even with this admission, MAS ODC continued to provide information to KL ACC that the aircraft was "*still sending movement messages*", and stated that:

> "*It was somewhere in Vietnam and coordinates of its position as N14.90000 E109 15500 at time 1833 UTC [0233 MYT]".*

(2) KL ACC then relayed the position information to HCM ACC at 1837:41 UTC [0237:41 MYT] informing HCM ACC that MH370 was still flying.

(3) To understand how the *Flight Explorer* works, the Team requested for a copy of the *Flight Explorer User Manual* and was informed that there was none in the office. Later, a copy of the *Flight Explorer User Manual* was provided to the Team.

Note:

Flight Explorer is a computer-based system which is also known as "Flight-Following System" to track aircraft based on input of the aircraft's Flight Plan data into the computer. The Flight Plan data generates the flight profile and position of the aircraft and updates every 30 minutes. However, the system does not provide real-time tracking.

(4) Whilst air traffic Controllers' communication with airline operators to obtain flight information is a normal occurrence, however information provided ought to be evaluated and assessed with due diligence as to its accuracy and relevancy. The information of the FFS on MH370 was derived from the *Flight Explorer* which did not provide real-time tracking. The *Flight Explorer* was neither a part of the ATS system nor documented in the Manual of ATS (MATS), International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual Volume IV, Standard Operating Procedure for SAR, Supplementary Operations Instructions (SOIs) or other documents. Therefore, the information derived from the FFS from ODC did not help at all but, instead, further complicated the situation**.**

The Team noted that MAS FFS was not part of the KL ACC Air Traffic Services system and it did not provide real-time tracking of flight. The position information of MH370 provided to KL ACC were computer-generated and not actual.

j) Communication Exchanges between KL ACC and HCM ACC and KL ACC and MAS Operations Despatch Centre on MH370

(1) The period between 1739 UTC [0139 MYT] and 2120 UTC [0520 MYT] revolved with ATC communications activities between HCM ACC and KL ACC, and. between KL ACC and ODC, for information on MH370. It also included KL ACC requesting HCM ACC to check with the adjacent FIRs namely SANYA, HONG KONG and BEIJING.

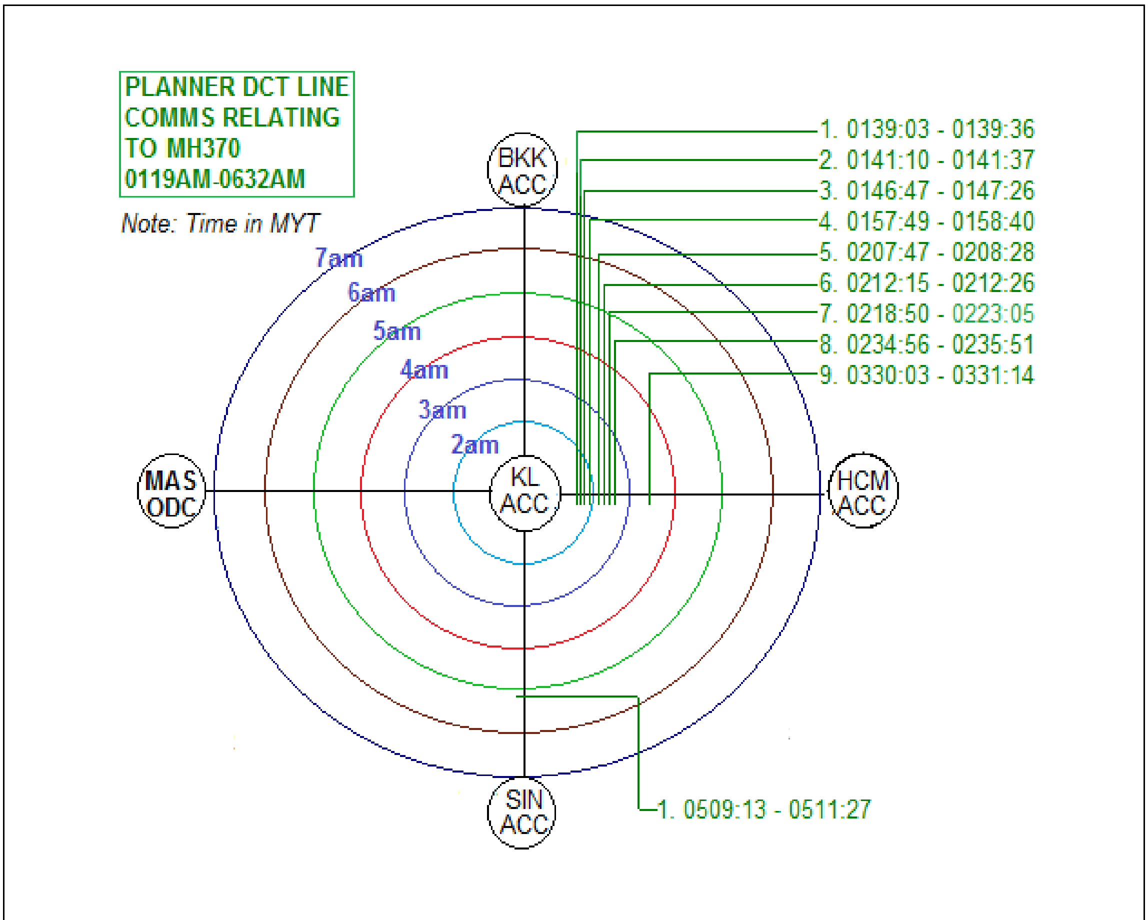

Figure 2.2J - Planning Controller Direct Telephone Line Communication Exchanges between KL ACC and HCM ACC, KL ACC and Singapore ACC from 0119 to 0632 [MYT]

(2) The time and the Planning Controller's direct line communications exchanges with HCM ACC, and Singapore ACC, from 1719 to 2232 UTC [0119 to 0632 MYT], is illustrated in concentric circles *(Figure 2.2J above)* when MH370 went missing. The illustrations at 0100 (MYT) begins with the innermost concentric circle followed by 0200 [MYT] on the next concentric circle with 0700 [MYT] on the outermost concentric circle (it depicts the timeline for 08 March 2014 on the KL ACC Planning Controller's direct line

communication exchanges with HCM ACC and with Singapore ACC from 0119 to 0632 [MYT] when MH370 was missing).

(3) Direct line communication exchanges (time in MYT) between KL ACC Planning Controller and HCM ACC.

No.	Time [MYT]	Direct-Line Communication Exchanges
1.	0139:03 - 0139:36	HCM ACC initiated the call to enquire about MH370 and notified KL ACC verbal contact was not established with MH370 and the radar target was last seen at BITOD.
2.	0141:10 - 0141:37	KL ACC initiated the call to inform HCM ACC that MH370 did not contact KL ACC after IGARI. HCM ACC informed KL ACC that "*we have radar contact but not verbal contact until BITOD, we are no ADS-B identity and no radar contact."*
3.	0146:47 - 0147:26	HCM ACC initiated the call /query about MH370 and stated that *"we have radar contact over IGARI not verbal contact and after BITOD we have no radar ident also ADS-B identity. And we call him many times until more than 20 minutes".* KL ACC responded: *"Okay, I will try...give a call and then."*
4.	0157:49 - 0158:40	HCM ACC initiated the call/query and stated: "*we officially no contact from MH370 until now, and we tried on many frequencies and all the aircraft - calling no response from MH370."* HCM ACC added and requested by saying: *"Could you check back for your side?"* KL ACC responded: "*Okay we will do that and the first at IGARI did you ever in contact with the aircraft or not first place."* HCM ACC replied: "*Negative sir, we have radar contact only but not verbal contact."* KL ACC responded: "*But no when passed IGARI, did the aircraft call you?"* HCM ACC replied: *"Negative sir."* KL ACC responded: *"Negative. Why you didn't tell me first within five minutes you should be called me?"* KL ACC, before ending the conversation, indicated that he would try to call the Company.

Table 2.2F - Direct Line Communication Exchanges between KL ACC and HCM ACC

cont…

(3) Direct line communication exchanges (time in MYT) between KL ACC Planning Controller and HCM ACC *(cont…)*

No.	Time [MYT]	Direct-Line Communication Exchanges
5.	0207:47 - 0208:28	HCM ACC initiated the call query to KL ACC for confirmation that MH370 was in Phnom Penh FIR as Phnom Penh did not have any information on MH370.KL ACC responded that he would check with his supervisor again.
6.	0212:15 - 0212:26	KL ACC while coordinating with HCM ACC on another traffic informed that there was no update on the status of MH370.
7.	0218:50 - 0223:05	KL ACC initiated the call and queried if the flight plan routing of MH370 was supposed to enter Cambodian airspace. HCM ACC confirmed that the planned route was only through the Vietnamese airspace. HCM ACC also informed that it had checked and also been advised by Cambodia that it had no information or contact with MH370. HCM ACC confirmed that earlier information on loss of radar contact after BITOD, and radio contact, was never established. KL ACC queried if HCM ACC was taking Radio Failure action but the query did not seem to be understood by the personnel. HCM ACC suggested KL ACC to call MAS Operations and was advised that it had already been done.
8.	0234:56 - 0235:51	HCM ACC initiated the call and queried about the status of MH370 and was informed by KL ACC that the Watch Supervisor was talking to the Company at that time.
9.	0330:03 - 0331:14	KL ACC initiated the call and enquired on news of MH370 and HCM ACC responded: "*not yet.*" KL ACC queried whether HCM ACC had checked with the next FIR Hainan.

Table 2.2F - Direct Line Communication Exchanges between KL ACC and HCM ACC

(4) Direct line communication exchange (time in MYT) relating to MH370 between KL ACC and Singapore ACC *(Table 2.2G* below)

No	Time [MYT]	Direct-Line Communications Exchanges
1.	0509:13 - 0511:27	Singapore ACC initiated the call and informed that it was first alerted by Hong Kong ACC who had made enquiries to ascertain the status of MH370. KL ACC confirmed that it was in contact with MH370 until transferred at IGARI and that MAS on the ground had also no contact with MH370.

Table 2.2G - Direct Line Communication Exchanges between KL ACC and Singapore ACC

(5) *Figure 2.2K* below illustrates the time and the Radar Controller's direct line communications exchanges relating to the missing MH370 between KL ACC and HCM ACC, and between KL ACC and ODC.

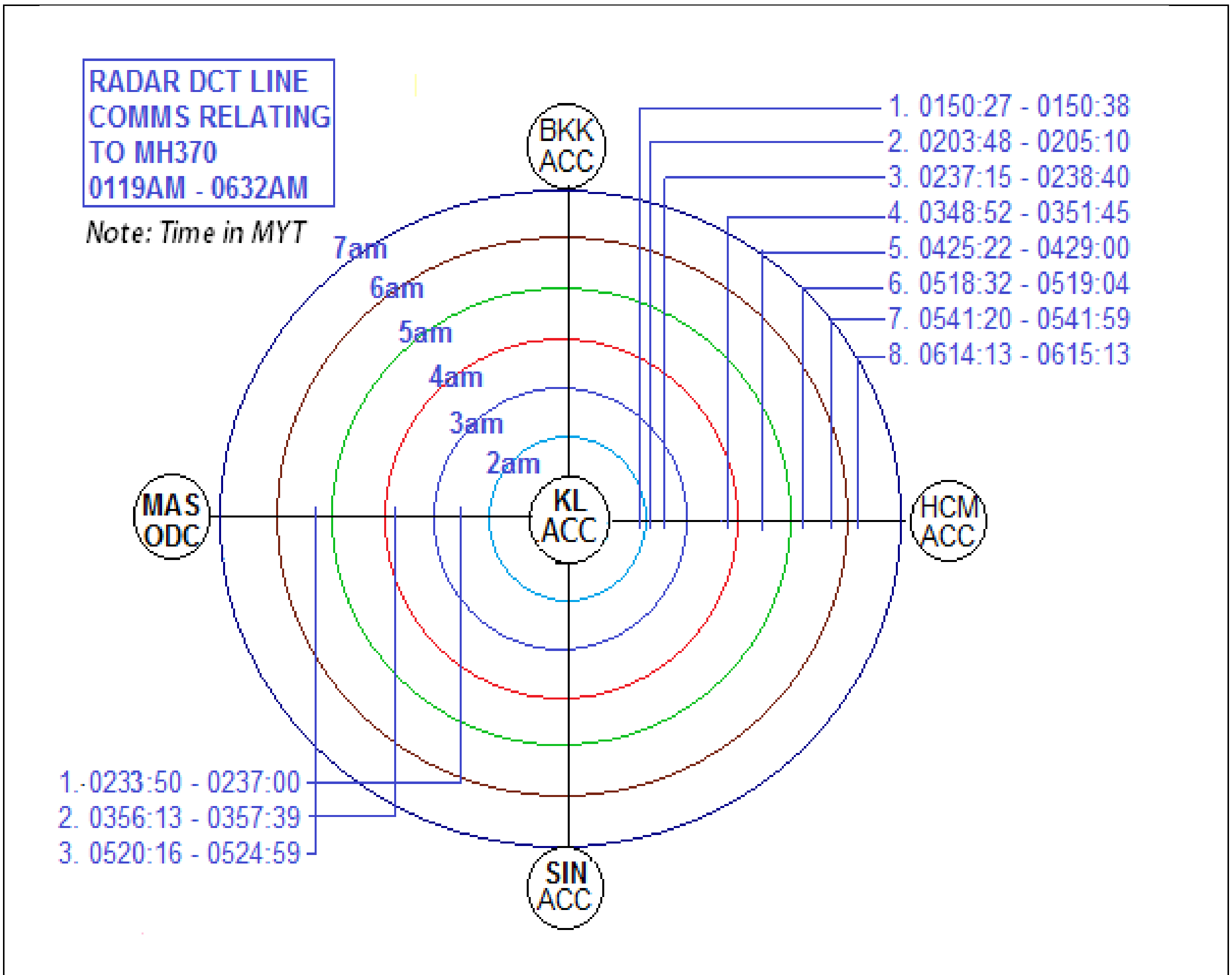

Figure 2.2K - Radar Controller's Direct Line Communication Exchanges

It begins with 0100 [MYT] at the innermost concentric circle followed by 0200 [MYT] on the next concentric circle with 0700 [MYT] on the outermost concentric circle (it depicts the timeline for 08 March 2014 on the KL ACC Radar Controller direct line communication exchanges with HCM ACC and ODC 0119 to 0632 [MYT] when MH370 went missing).

(6) Direct line communication exchanges between KL ACC Radar Controller and HCM ACC (*Table 2.2H*, below)

No.	Time [MYT]	Direct-Line Communications Exchanges
1.	0150:27 - 0150:38	KL ACC initiated the call to enquire about MH370 and HCM ACC replied: "*negative contact.*"
2.	0203:48 - 0205:10	KL ACC initiated the call query to HCM ACC on the status of MH370. HCM ACC confirmed there was no radar contact at that time and no verbal communication was established. KL ACC relayed the information received from MAS Operations that MH370 was in Cambodian airspace.
3.	0237:15 - 0238:40	KL ACC initiated the call and informed HCM ACC that MH370 was still flying, and that the aircraft was sending position reports to the airline. KL ACC then relayed to HCM ACC the position of MH370 in latitude and longitude as advised by MAS Operations Centre.
4.	0348:52 - 0351:45	KL ACC initiated the call and queried HCM ACC for news of MH370. HCM ACC replied: "*Until now nothing.*" KL ACC suggested checking with the next FIR and HCM ACC advised: "*It was SANYA FIR and he had checked with SANYA FIR but no response until now*."
5.	0425:22 - 0429:00	HCM ACC initiated the call and queried to confirm the last position that MH370 was in contact with KL ACC. KL ACC replied: *"The last position we contact that was about IGARI."*

Table 2.2H - Direct Line Communication Exchanges between KL ACC Radar Controller and HCM ACC

cont…

(6) Direct line communication exchanges between KL ACC Radar Controller and HCM ACC (*Table 2.2H*, below)..*cont.*

No.	Time [MYT]	Direct-Line Communications Exchanges
6.	0518:32 - 0519:04	HCM ACC initiated the call and queried for information on MH370. KL ACC queried if any information had been received from Hong Kong or Beijing.
7.	0541:20 - 0541:59	HCM ACC initiated the call and queried for any updates.
8.	0614:13 - 0615:13	KL ACC initiated the call and queried HCM ACC if SAR was activated.

Table 2.2H - Direct Line Communication Exchanges between KL ACC Radar Controller and HCM ACC

(7) Direct line communication exchanges between KL ACC and ODC (*Table 2.2I* below)

No.	Time [MYT]	Direct-Line Communications Exchanges
1.	0233:50 - 0237:00	KL ACC informed MAS that HCM ACC still had no contact with MH370. MAS informed that the aircraft was still sending movement messages and providing latitude 14.90000 longitude 109.15500 at 1833 UTC [0233 MYT].
2.	0356:13 - 0357:39	KL ACC initiated the call and enquired about MH370. MAS replied: *"Not yet".*
3.	0520:16 - 0524:59	KL ACC initiated the call and queried MAS for news on MH370. The Technical Captain said: *"Whatever we have here suggest that the aircraft had never leave Lumpur airspace because he has failed to call Ho Chi Minh"* and suggested to KL ATSC to trace back the record, voice recording and time of the positive handover to Ho Chi Minh. KL ACC replied: *"I wake up my supervisor and ask him to check again to go to the room and check what, what the last contact all this thing."*

Table 2.2I - Direct Line Communications Exchanges between KL ACC and ODC

Investigation revealed that between 0119 and 0632 MYT, the following ATC communications activities on MH370, between HCM ACC and KL ACC, and between KL ACC and ODC, took place:

- There were nine instances KL ACC Sector 3+5 planner Controller communicated with HCM ACC and one with Singapore ACC relating to MH370, and

- There were eight instances KL ACC Sector 3+5 Radar Controller communicated with HCM ACC and three with ODC relating to MH370,

Figure 2.2L (below) illustrates the time and the Radar Controller's direct line communications exchanges, though not relating to the missing MH370, with HCM ACC and Singapore ACC, from 0119 to 0632 [MYT].

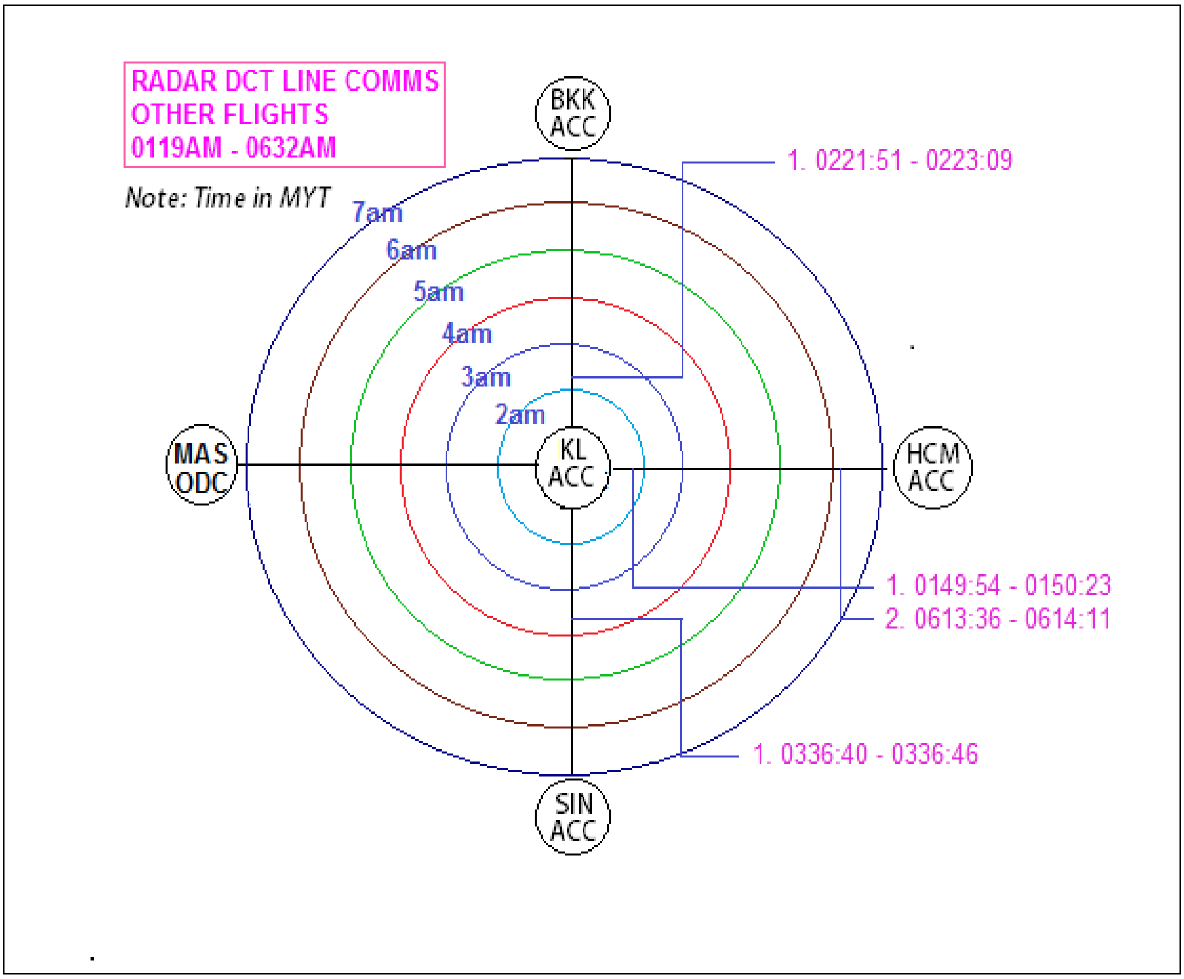

Figure 2.2L - Radar Controller direct telephone line communications exchanges between KL ACC and HCM ACC, KL ACC and Bangkok ACC, KL ACC and Singapore ACC from 0119 to 0632 [MYT] not related to MH370

Figure 2.2M (below) illustrates the time and the Planning Controller's direct line communications exchanges not relating to the missing MH370 with HCM ACC, Singapore ACC and Bangkok ACC, from 0119 to 0632 [MYT]. It begins at 0100am at the innermost concentric circle followed by 0200 [MYT] on the next concentric circle with 0700 [MYT] on the outermost concentric circle (it depicts the timeline for 08 March 2014 on KL ACC Planning Controller direct line communications exchanges with between KL ACC and HCM ACC, KL ACC and Bangkok ACC, KL ACC and Singapore ACC from 0119 to 0632 [MYT] when MH370 went missing).

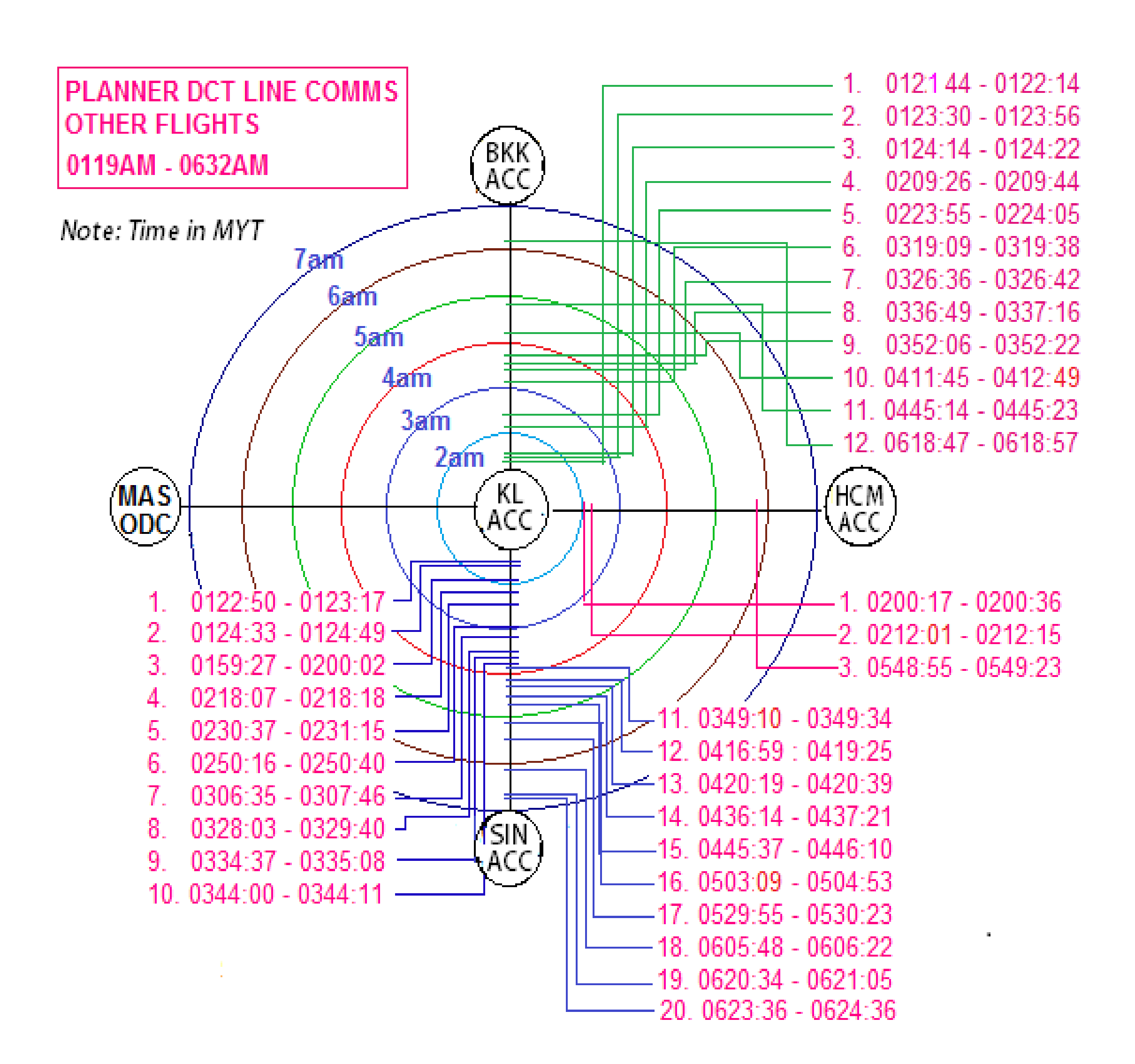

Figure 2.2M - Planning Controller's direct telephone line communications exchanges between KL ACC and HCM ACC, KL ACC and Bangkok ACC, KL ACC and Singapore ACC from 0119 to 0632 [MYT] not related to MH370

It begins at 0100 [MYT] at the innermost concentric followed by 0200 [MYT] on the next circle with 0700 [MYT] on the outermost concentric circle (it depicts the timeline for 08 March 2014 on KL ACC Radar Controller direct line communications exchanges between KL ACC and HCM ACC, KL ACC and Bangkok ACC, KL ACC and Singapore ACC, from 0119 to 0632 [MYT] when MH370 went missing).

The Team noted that between 0119 and 0632 MYT:

- there were two instances KL ACC Sector 3+5 Radar Controller communicated with HCM ACC, one with Bangkok ACC and another with Singapore ACC relating to other flights; and
- there were three instances Sector 3+5 planner Controller communicated with HCM ACC, twelve instances with Bangkok ACC and twenty with Singapore ACC relating to other flights.

k) Delegation of Airspace by Singapore Area Control Centre to KL ACC

i) The delegated airspace *(Figure 2.2N* below) is a portion of airspace within the Singapore FIR over the South China Sea. IGARI is a waypoint along airway M765 which is within the delegated airspace. KL ACC is responsible for the provision of air traffic services to flights operating within the delegated airspace and Singapore ACC is responsible for the provision of SAR service.

ii) At 2109:13 UTC [0509:13 MYT] Singapore ACC contacted KL ACC for information on MH370 following an enquiry on the status of the aircraft by Hong Kong ACC four minutes earlier. By then, over three and a half hours had lapsed.

iii) At 0230 UTC 08 March 2014, KL ARCC advised Singapore RCC on the situation relating to MH370. Singapore RCC informed that a Hercules aircraft (C-130) would be launched to the search area with clearance from Ho Chi Minh. The Hercules aircraft (C-130) was assigned the radiotelephony callsign as *Rescue 71* by Lumpur ARCC.

iv) Although Singapore ACC is responsible for the provision of SAR service within the delegated airspace, KL ACC did not inform Singapore ACC when MH370 was overdue. Nevertheless, Singapore RCC launched a search and rescue aircraft to the search area after KL ARCC advised on the situation relating to MH370.

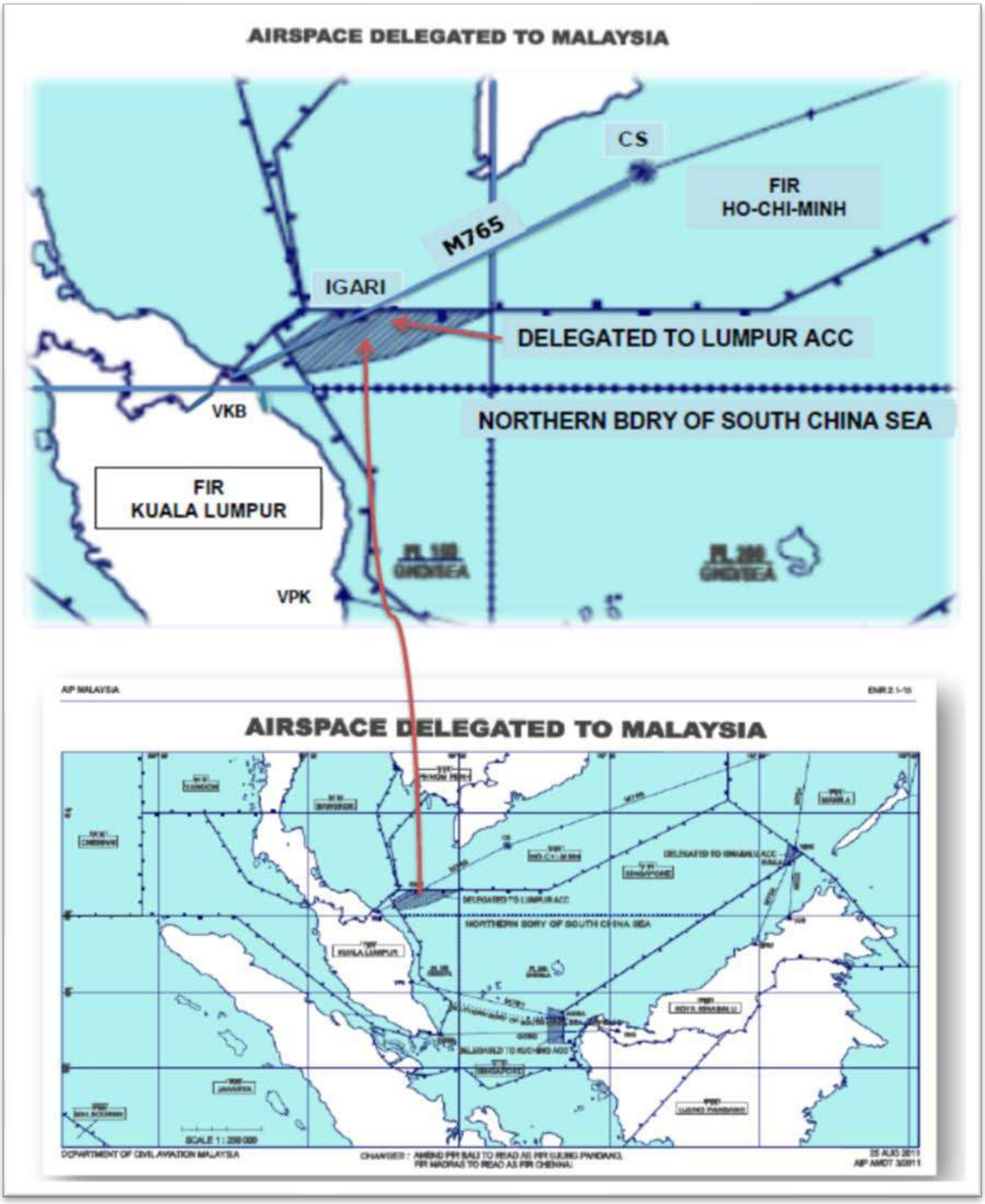

Figure 2.2N - Singapore Airspace delegated to Malaysia

Source: DCA Malaysia

l) ATC Actions on Strayed/Unidentified Aircraft (Primary Radar Target) within the Area of Responsibility

i) At 1730:37 UTC [0130:37 MYT] a strayed/unidentified aircraft (primary radar target) appeared on the Sector 3+5 radar display at approximately 57 nm north east of Kota Bahru and heading to Kota Bahru. This aircraft target dropped off from the radar display at 1737:22 UTC [0137:22 MYT]. It reappeared at 1738:56 UTC [0138:56 MYT], on airway B219 heading towards VPG[36] and dropped off at 1744:52 UTC [0144:52 MYT]. The appearances and reappearances of these strayed/unidentified primary targets on Lumpur Sector 3+5 radar display were for a duration of 6 minutes 45 seconds and 5 minutes 56 seconds respectively. The duration of the strayed/unidentified aircraft appearing on the Lumpur Sector 3+5 radar display was 12 minutes and 41 seconds. When the strayed/unidentified aircraft continued its journey towards VPG, it entered into the Lumpur Sector 1 Area of Responsibility.

ii) On the Lumpur Sector 1 radar display, the strayed/ unidentified aircraft (primary radar target) appeared at 1747:02 UTC [0147 MYT] and dropped off at 1748:39 UTC [0148:39 MYT]; and reappeared at 1751:45 UTC [0151:45 MYT] and dropped off at 1752:35 UTC [0152:35 MYT]. The duration of the strayed/ unidentified aircraft appearing on Lumpur Sector 1 radar display was 2 minutes 27 seconds.

<u>Note</u>

Information on strayed/unidentified aircraft (primary radar target) was obtained from radar recording playback.

iii) In interviews with the ATCOs on duty, the Sector 3+5 and Sector 1 Radar Controllers informed that they were unaware of the strayed/unidentified aircraft (primary radar target) transiting their AORs.

The Sector 3+5 Radar Controller acknowledged that he had to shift his attention to four other aircraft in another area, viz. VPK approximately 214 nm south of IGARI). As such, he did

[36] VPG – Penang DVOR/DME coordinates 051646.7N 1001537.4E.

not observe the strayed/unidentified aircraft (primary radar target).

The Sector 1 Radar Controller stated that he did not observe the strayed/unidentified aircraft (primary radar target) even though he remained at the Controller working position.

MATS Vol 1, Part 1 - ADMIN page 1-1-4 para 1.2.2 which stipulates that:

Air Traffic Controller is responsible:

- *for maintaining a continuous watch on their assigned communications channels or radar displays.* (Point No. 5)

MATS PART 9 - EMERGENCIES, SECTION 15, page 9-15-1 (and ICAO Annex 11 - Air Traffic Services Chapter 2, para. 2.24.1, page 2-14) on *Strayed or unidentified aircraft* states:

1.5.2 The terms "strayed aircraft" and "unidentified aircraft" have the following meanings:

a) Strayed aircraft - An aircraft that has deviated significantly from its intended track or which reports that it is lost.

b) *Unidentified aircraft - An aircraft that has been observed or reported to be operating in a given area but whose identity has not been established.*

ATS PART 9 – EMERGENCIES, SECTION 15, para 15.4, page 9–15–2 (also ICAO Annex 11 - Air Traffic Services Chapter 2, para. 2.24.1.2, page 2-15) stipulates*:*

15.4 As soon as Controllers become aware of an unidentified aircraft operating in their area of responsibility, they shall endeavour to establish the identity of the aircraft for the provision of air traffic services or as required by the appropriate military authorities in accordance with local instructions. Towards this end, Controllers shall take such action as appropriate to establish two-way communication with the aircraft:

a) inquire of other ATS units within the FIR about the flight and request their assistance to establish two-way communication with the aircraft;

b) inquire of ATS units in adjacent FIRs about the flight and request their assistance to establish two-way communication with the aircraft;

c) attempt to obtain information from other aircraft in the area; and

d) notify the appropriate military unit as soon as the identity of the aircraft has been established.

m) KL ATSC Duty Shift System for Air Traffic Controllers

i) 4-cycle Shift System

The 4-cycle shift system (*Table 2.2J* below) for the KL ATSC was, as follows:

Day	Shift	Start	End
1	Afternoon	0500 UTC [1300 MYT]	1100 UTC [1900 MYT]
2	Morning	2300 UTC [0700 MYT]	0500 UTC [1300 MYT]
	Night	1100 UTC [1900 MYT]	1600 UTC [2400 MYT]
3	Morning	1600 UTC [0000 MYT]	2400 UTC [0700 MYT]
4	Off Duty		

Table 2.2J - 4-cycle Shift System of KL ATSC

ii) Operations in Restricted/Collapsed Mode

(1) From 1600 UTC [0000 MYT] until 2200 UTC [0600 MYT] the number of Controllers in the KL ATSC was scaled down by half to enable the Controllers to take a scheduled break from duty:

- the first group from 1600 UTC [0000 MYT] to 1900 UTC [0300 MYT] and
- the second group from 1900 UTC [0300 MYT] to 2200 UTC [0600 MYT].

This practice had been approved by DCA. According to DCA, the scale-down of personnel during lean hours is a norm in air traffic control centres all around the world where air traffic services can continue safely.

(2) MATS 1 Part 2 Section 2 para. 2.3.6, page 2-2-3 stipulates that:

The Supervisor may give periods of relief during a shift to personnel:

- *by arranging for relief personnel if possible; or by combining operating positions provided current and anticipated workload permits and the personnel on relief can be recalled quickly; or*
- *by rotating personnel to less active positions.*

(3) DCA Unit Administrative Instruction UAI 7/2010 details on how shift duty Air Traffic Controllers have their breaks during night shift work where the number of traffic movements is substantially reduced during the early morning period between 0000-0600 hours. Between the hours of 1600-1900 UTC [0000-0300 MYT] and 1900-2200 UTC [0300-0600 MYT], the shift is undertaken by two teams by combining the six working positions into four. However, though combined, they still would cover all the working positions.

(4) The 'Shift Break Time' in *Table 2.2K* below illustrated the manner the Controller working positions was managed. Based on this table, the Controller working positions on the 07 March 2014 is tabulated as shown in the two tables below:

- *Table 2.2L - Controller Working Positions between 1600-1900 UTC [0000-0300 MYT],* and
- *Table 2.2M - Controller Working Position between 1900-2200 UTC [0300-0600 MYT].*

From 1600 to 1900 UTC [0000-0600 MYT] Sectors 3 and 5 were combined while Sectors 1, 2 and 4 remained status quo.

FORM ATCC/OPS(IV)pind.1/10

SHIFT BREAK TIME

TPP BERTUGAS				
NO	**NAME**	**POSITION**	**POSITION TO BE COVERED**	**TIME**
1		BC	BA	0000 - 0300
2		CA	CA	
3		BD	BB & CB	
4		CD	CD & EB	
5		BE	BC	
6		BF	CC	
7		ED	ED	
8		EE	EC	
9		EA	EA	
10		EF1	EI & EF	
11		EH1	EH	
12		FA3	EB (0000-0200)	
1		BB	BA	0300 -0600
2		CB	CD	
3		BA	BB	
4		CE	BC &CC	
5		CC	CA	
6		EB	ED	
7		EF2	EC & EE	
8		EI	EI & EF	
9		EH2	EH	
10		EC	EB	
1		AF	APP	0000 - 0115
2		AN	APP	0115 - 0230
3		AL	APP	0230 - 0345
4		AS	APP	0345-0500
5		AA	APP	0500-0615
1		EG	CB	0000-0200
2		FB	CPDLC	
1		EG	ANY POSN	0530-0630
2		FB	ANY POSN	
		TRAINING / FAMILIARIZATION		
1			ANY POSN	0000 - 0130 & 0530-0630
2				
3				
4				
5				

NOTE 1: Fs SHALL BREAK INTO 2 DURING RESTRICTED WATCH.HOWEVER IF B3 IS NOT AVAILABLE; F SHALL COVER CD POSITION UNTIL 0200 AND BE BACK BY 0530.THE OTHER F SHALL COVER 'C' FROM 0000-0200.

NOTE 2 THE 2ND RESTRICTED WATCH SHIFT SHALL REMAIN AT THEIR RESPECTIVE P(UNTIL RELEIVED BY 1ST RESTRICTED WATCH SHIFT

NOTE 3: WHEN W/S IS RESTING THE SHIFT LEADER SHALL TAKE CHARGE. IF URGENT W/S SHALL BE INFORMED IMMEDIATELY.

NOTE 4: WHEN TFC PERMIT X SHALL PERFORM CPDLC TRIAL FROM 0200-0300

NOTE 5: C3 SHALL REMAIN AT 'U' PSN 1100-0000

APPROVED BY :

....

WATCH MANAGER
ATCC KL FIR

Legends

FS	ATSC Supervisor	**BA**	Sector 1 Radar	**CA**	Sector 1 Area Proc	**FB**	CPDLC
AA	TMA Supervisor	**BB**	Sector 2 Radar	**CB**	Sector 2 Area Proc	**EG**	Clearance Delivery
AN	Approach North	**BC**	Sector 3 Radar	**CC**	Sector 3 Area Proc	**RC**	Relief
AS	Approach South	**BD**	Sector 4 Radar	**CD**	Sector 4 Area Proc	**P**	Check Officer/ Candidate
AL	Approach Low	**BE**	Sector 5 Radar	**CE**	Sector 5 Area Proc	**T**	Training
AF	Flow Control	**BF**	Sector 6 Radar (Sec 1 Upper)	**CR**	Area Proc Relief	**FAM**	Familiarisation
AR	APC ADAR Relief	**BG**	Sector 7 Radar			**F**	Extra Controller
		BH	Area Radar Relief				

Table 2.2K - Shift Break Time

No.	Position	Position To Be Covered	Time (MYT)
1.	Sector 1 Planner	Sector 1 Planner	0000 - 0300
2.	Sector 4 Planner	Sector 4 Planner and Sector 2 AFD	
3.	Sector 3 Radar	Sector 1 Radar	
4.	Sector 4 Radar	Sector 2 Planner and Radar	
5.	Sector 5 Radar	Sector 3 + 5 Radar	
6.	Sector 6 Radar	Sector 3 + 5 Planner (working position not covered by Sector 6 Radar)	
7.	Sector 4 AFD	Sector 4 AFD	
8.	Sector 5 AFD	Sector 3 + 5 AFD and also cover as Sector 3 + 5 Planner	
9.	Sector 1 AFD	Sector 1 AFD	
10.	AFD/FDP 1	Assist FIS & AFD/FDP	
11.	Assist Clearance Delivery 1	Assist Clearance Delivery	
12.	FIS 3	AFD (0000-0200 UTC)	

Table 2.2L - Controller Working Positions between 0000-0300 MYT

No.	Position	Position To Be Covered	Time (MYT)
1.	Sector 2 Radar	Sector 1 Radar	0300 - 0600
2.	Sector 2 Planner	Sector 4 Planner	
3.	Sector 1 Radar	Sector 2 Radar	
4.	Sector 5 Planner	Sector 3+5 Planner and Sector 3+5 Radar.	
5.	Sector 3 Planner	Sector 1 Planner	
6.	Sector 2 AFD	Sector 4 AFD	
7.	AFD/FDP	Sector 3+5 AFD and also cover as 3+5 Planner	
8.	Assist FIS	Assist FIS & AFD/FDP	
9.	Assist Clearance Delivery	Assist Clearance Delivery	
10.	Sector 3 AFD	Sector 2 AFD	

Table 2.2M - Controller Working Positions between 0300-0600 MYT

(5) This analysis is based on the Air Traffic Controller Duty Roster for the month of March 2014, DCA Unit Administrative Instruction UAI 7/2010 and the entry recorded by the WS in the WS ATS logbook on 07 March 2014. From 1500 UTC [2300 MYT] until 1900 UTC [0300 MYT] and 1900 UTC [0300 MYT] until 2200 UTC [0600 MYT] the Sector 3+5 radar working position was manned by a radar-rated Controller. The Controller working positions (CWPs) between 0000 - 0300 MYT on the night of 07 March 2014, as shown in item 6 of *Table 2.2K* above revealed that the Sector 6 Radar Controller who was supposed to cover the Sector 3+5 planner position was not rostered by the ATSC Duty Watch Supervisor (the Radar Controller was rostered to work between 0300 - 0600 MYT). Consequently, the CWP for Sector 3 which was combined with Sector 5 at 1500 UTC [2300 MYT] was manned by a Radar Controller and an assistant flight data (AFD) Controller. Since the CWP planner was not covered (item 8 of *Table 2.2G* above), the AFD Controller stepped in as Sector 3+5 planner (albeit untrained for the planner position). From 1900-2200 UTC [0300 - 0600 MYT], a Radar Controller had to cover the Sector 3+5 radar and planner position (refer item 4 of *Table 2.2H*, above with an AFD Controller (refer to item 7 of *Table 2.2M*) who also stepped in as Sector 3+5 planner.

(6) In interviews with the ATCOs, the Team noted that when the planner positions were not covered, the AFD Controllers would step in as planners to assist the Radar Controllers as this had been the practice.

Shift personnel during scheduled break are allowed to rest in the rest area adjacent to the ATSC. The ATSC Duty Watch Supervisor maintains his/her watch at the Operational Centre until 1730 UTC [0130 MYT]. He/she takes his/her break until 2130 UTC [0530 MYT]. During his/her absence, a shift leader (usually the most senior Controller) is appointed to take charge but the ATSC Duty Watch Supervisor can be recalled at a moment’s notice should the need arises.

(7) On the night of 07 March 2014, at 1500 UTC [2300 MYT] the Subang ATSC radar maintenance contractor at KL ATSC received a request from the Sector 5 Air Traffic Controller to absorb functions of control for Sector 5 into Sector 3. The request was successfully executed by the Site Maintenance Engineer (SME).

(8) In interviews with the ATCOs and on listening from the play-back of the direct telephone line recording on the Planning Controller working position, it is confirmed that, from 1600 UTC [0000 MYT] till 2200 UTC [0600 MYT], the Planning Controller working position (*Table 2.2N,* [below]) was manned by unrated Air Traffic Controllers as follows:

No.	Time	Sector 3 + 5 Planner Position
1	1600 UTC [0000 MYT] until 1730 UTC [0130 MYT]	Manned by an unrated ATCO
2.	1730 UTC [0130 MYT] until 1900 UTC [0300 MYT]	Manned by AFD Controller - untrained and unrated.
3.	1900 UTC [0300 MYT] until 2200 UTC [0600 MYT]	

Table 2.2N - Planning Controller Position between 1600-2200 UTC

The Team noted that during the operations in restricted/collapsed mode between 1600 UTC [0000 MYT] and 2200 UTC [0600 MYT], untrained and unrated Air Traffic Controller were manning the Planning Controller working position

n) Roles played by the Duty ATSC Watch Supervisor

i) Refer to *para. 2.2.2 para. l) (5).* b) MATS PART 1 - ADMIN, para 1.2.2, page 1-1-3 stipulates that:

<u>*Watch Supervisor* - responsible for</u>:

- *ensuring that the operating positions are manned adequately by personnel qualified and current in practice.* (Point No. 3).
- *ensuring that staff are operationally proficient (Point No. 4).*

ii) In interviews with the ATCOs on shift duty on the day of the disappearance of MH370, the AFD Controllers confirmed that they were performing the functions as Planning Controller for Sector 3+5 from 1600 UTC [0000 MYT] to 2200 UTC [0600 MYT].

iii) Based on transcripts of the planner's direct telephone line (refer *Factual Information, Appendix 1.18G, pages 1-164*), from 1620 UTC [0020 MYT] to 2200 UTC [0600 MYT], a total of forty-one (*Table 2.2O* below) Planning Controller's direct telephone line exchanges took place - thirty-eight by three ATCOs (one trainee and two AFD Controllers performing the functions of Planning Controller) and the remaining three by a Radar Controller.

<table>
<tr><th rowspan="2">No.</th><th colspan="3">ATCO</th><th rowspan="2">REMARKS</th></tr>
<tr><th>Radar</th><th>Planning (3+5)</th><th>Trainee & AFD</th></tr>
<tr><td>1.</td><td>2</td><td>8</td><td>-</td><td>Relating to MH370</td></tr>
<tr><td>2.</td><td>1</td><td>25</td><td>5</td><td rowspan="3">Not relating to MH370 (mainly coordination with BKK, HCM and SIN</td></tr>
<tr><td>Sub-Total</td><td>3</td><td>33</td><td>5</td></tr>
<tr><td>Total</td><td colspan="3">41</td></tr>
</table>

Table 2.2O - Planner Direct Line Telephone Exchanges

o) Activation of Aeronautical Rescue Coordination Centre

In interviews conducted with the SAR-trained Controller, the Team noted that the Aeronautical Rescue Coordination Centre (ARCC) was activated (*Figure 2.2O - ARCC Activation Form,* below) at 2130 UTC [0530 MYT]. After the activation, the Search and Rescue Mission Coordinator (SARMC) did not have sufficient details to act upon before the distress message was disseminated at 2232 UTC [0632 MYT]. The SARMC also informed the Team that the ARCC did not receive any alerting message from Ho Chi Minh via the Aeronautical Fixed Telecommunication Network (AFTN).

DCA/ASAR/FORM/01

JABATAN PENERBANGAN AWAM MALAYSIA
Department of Civil Aviation Malaysia (DCA)
AERONAUTICAL RESCUE COORDINATION CENTRE
BLOK B, KOMPLEKS KAWALAN TRAFIK UDARA
LAPANGAN TERBANG SULTAN ABDUL AZIZ SHAH
47200 SUBANG, SELANGOR DARUL EHSAN

Telephone No: *xx-xxxx xxxx (number redacted)*
Fax No: *xx-xxxx xxxx (number redacted)*

AIRCRAFT INCIDENT NOTIFICATION AND AERONAUTICAL RESCUE COORDINATION CENTRE ACTIVATION

TO :

	AGENCY	FAX	TEL
1	POTU	*xx-xxxx xxxx (number redacted)*	*xx-xxxx xxxx (number redacted)*
2	MRCC	*xx-xxxx xxxx (number redacted)*	*xx-xxxx xxxx (number redacted)*
3	MCC	*xx-xxxx xxxx (number redacted)*	*xx-xxxx xxxx (number redacted)*
4	UNIT UDARA BOMBA	*xx-xxxx xxxx (number redacted)*	*xx-xxxx xxxx (number redacted)*
5			

REF NO
1
DATE
8/3/2014
PAGE
1

1 **DISTRESS STAGE**

	ALERTFA
	INCERFA
X	DISTRESFA

INFORMATION OF THE INCIDENT				
Date	:	7/3/2014		
Time	:	17:19	UTC	
		01:19AM	Local	
Last Known Position	:	07 01' 36"		N
		103 31' 23"		E

2 **NATURE OF DISTRESS**

AIRCRAFT MISSING AFTER PASSED WAY POINT IGARI. NO DISTRESS CALL FROM THE PILOT REPORTED. KL ARCC ACTIVATED AT 0530 UTC.

3 **AIRCRAFT DETAILS**

Craft Callsign:	: MAS 370		Crew	:	12
Type:	: B777-200		Passenger	:	227
Point of Dep:	: WMKK, KUALA LUMPUR		Operator	:	MALAYSIA AIRLINE
Destination:	: ZBAA, BEIJING		Colour/Marking	:	WHITE/RED/BLUE
Route:	: R208 - IGARI - BITOD		Survival Equipment	:	

SUBMITTED BY : *xxxxxx (Name redacted)*
DUTY SAR MISSION CO-ORDINATOR
KUALA LUMPUR ARCC

TIME SUBMITTED	
21:30	UTC
5:30 AM	LOCAL

COMPLETE THE SECTION BELOW AND RETURN BY FAX TO RCC, IF APPLICABLE

4 **Request details on SRUs that are available for deployment for SAR:**

	Search Unit Craft/Personnel	DEPARTURE & ARRIVAL LOCATION		ETD	POB	Fuel	Cruise Speed	Search Speed
		Departure	Arrival					
1								
2								
3								
4								

5	*Please mark 'YES' if, NIL SRUs AT ALL, WILL ADVISE WHEN AVAILABLE*	YES

Note: PILOT TO BE PRESENT FOR PREFLIGHT BRIEFING AT THE KL AERONAUTICAL RESCUE COORDINATION CENTRE (KLARCC), SUBANG (TIME: BEFORE FLIGHT)

Figure 2.2O - Aircraft Incident and ARCC Activation Form

The Team noted that the distress message was disseminated an hour and two minutes after KL ARCC was activated. There was no alerting message from Ho Chi Minh RCC.

p) Play-back of Radar and Radiotelephony Recordings by ATSC Duty Watch Supervisor

At 2145 UTC [0545 MYT], the ATSC Duty Watch Supervisor requested from the radar maintenance personnel to carry out radar data play-back (with permission granted by KL ATSC's Chief Assistant Director). The SME successfully restored the desired file from the recording play-back back-up hard disc. At 2200 UTC [0600 MYT] the ATSC Duty Watch Supervisor performed radar data and voice recording play-back at the D40 Controller Working Position (D40 CWP).

q) Entries in ATS Logbooks of ATSC Watch Supervisor and Sector 3 Controller Working Position

MATS Part 1 - Admin, page 1-1-7 para 1.7 on recording of entries in the logbook states, as follows:

i. *The time of entries shall be based on UTC and events recorded in a chronological order;*
ii. *Entries shall give sufficient details to give readers a full understanding of all actions taken;*
iii. *The time an incident occurred and the time at which each action was initiated shall be stated.*

MATS PART 1 - ADMIN, para 1.7, page 1-1-7 further states that:

The ATS logbook serves to record all significant occurrences and actions relating to operations, facilities, equipment and staff at an ATS unit. It is an official document and, unless otherwise authorised, its content shall be restricted to those personnel requiring access to the information. All personnel should read those log entries of concern to them, which were made during the period since their last tour of duty before accepting responsibility for an operating position.

1.7.2 Where there is more than one unit within a facility, a logbook shall be maintained for each unit.

1.7.3 The Supervisor or the senior Controller on duty shall be responsible for opening, closing and maintaining the log as applicable. Any Controller may make an entry but all entries shall be made in an indelible manner and no erasure is permitted. Incorrect information shall be struck out and the correct information inserted and initiated.

1.7.4 Information to be recorded in the ATS log should, as appropriate to the facility, include such matters as:

a) Incidents, accidents, non-compliance with regulations or air traffic control clearance, regardless of whether an additional separate report is required;

b) Aerodrome inspection reports, details of work in progress, aerodrome closures, and other essential aerodrome information;

c) Changes in the status of facilities, service or procedure including communications difficulties and tests;

d) Time of receipt of significant meteorological reports, e.g. SIGMET;

e) Any occurrence of a significant nature;

f) Configuration and reconfiguration of operation positions;

g) Any dispensation against the regulations, or special authorisation given by the Director General;

h) Details of approval for Special VFR operations; and

i) Opening and closing of shift or watch.

1.7.5 Controllers should follow the following procedures for recording of entries in the log:

a) Each entry should be accompanied by the signature or the authorised initials of the Controller making the entry.

b) The time of entries shall be based on UTC and events recorded in a chronological order;

c) Entries shall give sufficient details to give readers a full understanding of all actions taken;

d) The time and incident occurred and the times at which each action was initiate shall be stated; and

e) An entry needs to be brought to the attention of the unit chief shall be so annotated to enable him to take follow up action.

1.7.6 If during an emergency or busy period, it is not possible to make detailed entries in the log at the time of occurrence, Controllers are permitted to keep rough notes with exact times. As soon as possible thereafter, a detailed entry shall be made in the log.

a) Extract from the Watch Supervisor Logbook

i. Entry 11 at 1600 - Restricted watch

1st: named
12 names for the "2nd" half)

ii. Entry redacted (12 names for the "1st" half) and 2nd named redacted (12 at 1800:

*At 1800UTC, I was informed by S3 radar (name redacted) Controller then Ho Chi Minh is enquiring the position of MAS370 B777 reg. 9MMRO estimate for IGARI 1720, with a cleared level 35,000 ft. MAS370 is from KLIA to Beijing (ZBBB) with 239 POB. The fact is at time 1719 UTC, Mr. xxxx (name redacted) made a transfer of comm. instruction to MAS370 (MAS370 contact HO Chi Minh 120.9) and the pilot acknowledged by reading its callsign (MAS370). (*The radar label as it rosses Igari eastbound was good, but about 4 to 5 miles east of Igari the radar label starts 'coasting'. *base on radar video recording).*

*Prior to opening up the *replay, Ho Chi Minh indicated the Mr. xxxx (name redacted) that they saw the target until Bitod. At 1815, I check with MAS OPS Centre in KLIA Mr. xxxx, (name redacted) and he mentioned that MAS370 is on their flight tracker and he was able to exchange signals with the flight.*

At 1930 UTC Mr. xxxx (name redacted) MAS OPS Centre call in and spoke to Mr. xxxx (name redacted), admitting that the 'flight tracker' is based on projection and could not be relied for actual positioning or search.

At 2130 I activated RCC by instructing Pn. xxxx (name redacted) to handle this case.

Until 2245 still no cospas sarsat signal receive at ATCC Subang and ATCC Singapore. I spoke to Mr xxxx (name redacted) - watch supervisor Singapore (night shift), he confirmed that the was no cospas sarsat signal pickup on aviation target, only maritime hits was observed.

At 2250 I spoke to Ho Chi Minh W/sup, and advise him that based of video recording, the target starts to coast out about 4 to 5 miles east of Igari.

L/E at 2200, PTU Mr. xxxx (name redacted) who is in xxxx (name of place redacted) was informed, PP En. xxxx (name redacted) was informed by xxxx (name redacted).

Late entry - note - at 1840 Mr. xxxx (name redacted) (MAS OPS) confirmed that MAS370 download from acft giving a coordinate of N14.9000 1091500E timed 1833.

Conclusion - Our response to this incident is based on input by Ho Chi Minh and MAS Operations Centre using their 'flight tracker'. MAS370 was well transferred comms to Ho Chi Minh and acknowledged the instruction by pilot. And lastly the *radar label started to coast about 5 NM. east of IGARI. Lumpur RCC responsibility is to assist Ho Chi Minh to locating the acft posn.*

r) Distress Message

i) The distress message (*DETRESFA*) is intended to convey pertinent information to the recipients that there is a situation wherein there is a reasonable certainty that an aircraft and its occupants are threatened by grave and imminent danger and require immediate assistance.

ii) The *DETRESFA* message with a date-time-group (DTG) 072232 UTC was transmitted at 2232 UTC [0632 MYT].

iii) The contents of the *DETRESFA* message, as shown in *Figure 2.2P* below was not composed in accordance with the standard specified in ICAO DOC 4444, Air Traffic Management (PANS-ATM) Chapter 11, Air Traffic Services Messages, Appendix 3 (*Figure 2.2Q* below). The errors are, as below:

(1) Appendix 3, page A3-9 (*Figure 2.2P* below)

Field type 7 - Aircraft identification and SSR mode and code FPL–MAS370–IS should be "MAS370/A2157"

(2) Appendix 3, page A3-14 (*Figure 2.2P* below)

Field type 13 - Departure aerodrome and time WMKK1635 should be "WMKK1642"

(3) Appendix 3, page A3-29 & A3-30 (*Figure 2.2P* below)

Omission of Field Type 20 - Alerting search and rescue information. This field consists of the following sequence of elements separated by spaces. Any information not available should be shown as "NIL" or "NOT KNOWN" and not simply omitted.

(4) Spelling of ***DESTRESF*A** should read ***DETRESFA*** (*Figure 2.2P* below)

```
KLA637 072232
SS WMKKZQZX WMKKZRZX
072232 WMFCZQZX
(ALR-DESTRESFA/WMFCZQZX/MISSING
-FPL-MAS370-IS
-B772/H-SDFGHIJ3J5M1RWXY/LB1D1
-WMKK1635
-N0470F290 DCT PIBOS R208 IKUKO/M081F330 R208 IGARI M765
 BITOD/N0480F330 L637 TSN/N0480F350 W1 BMT W12 PCA G221
 BUNTA/N0480F370 A1 IKELA/N0480F370 P901 IDOSI/N0480F390 DCT CH
 DCT BEKOL/K0900S1160 A461 YIN/K0890S1130 A461 VYK
-ZBAA0534 ZBTJ ZBSJ
-PBN/A1B1C1D1L1O1S2 DOF/140307 REG/9MMRO EET/WSJC0032 VVTS0042
 ZJSA0210 VHHK0233 ZGZU0304 ZHWH0356 ZPE0450 SEL/QRCS
 RMK/ACASII EQUIPPED
-E/0710 P/TBN R/UVE S/M J/LF D/8 290 GREY A/WHITE WITH RED AND
 BLUE STRIPE C/TBN)
```

JABATAN PENERBANGAN AWAM
PENGURUSAN TRAFIK UDARA
HQ
MALAYSIA
AIR TRAFFIC MANAGEMENT
DEPARTMENT OF CIVIL AVIATION

Source: DCA Malaysia

Figure 2.2P - DETRESFA Message sent over AFTN

Excerpt from ICAO DOC 4444, Air Traffic Management (PANS-ATM) Chapter 10, Air Traffic Services Messages, Appendix 3, Field Type 7

Appendix 3 *A3-9*

Field Type 7 — Aircraft identification and SSR mode and code

FIELD TYPE 7

Format: – (a) Max. 7 characters * / b c

SINGLE HYPHEN

(a) *Aircraft identification*

NOT MORE THAN 7 CHARACTERS, being the aircraft identification shown in the filed flight plan and composed as specified in Appendix 2, Section 2.

* This field may be terminated here in messages relating to flights operating within areas where SSR is not used, or when the SSR code information is not known or would not be meaningful to the accepting unit.

OBLIQUE STROKE

(b) *SSR mode*

LETTER A giving the SSR mode related to (c).

(c) *SSR code*

4 NUMERICS giving the SSR code assigned to the aircraft by ATS and transmitted in the mode given in (b).

Examples: –BAW902
–SAS912/A5100

Previous type of field or symbol	*This type of field is used in*	*Next type of field or symbol*
5	ALR	8
3	RCF	21
3	FPL	8
3	CHG	13
3	CNL	13
3	DLA	13
3	DEP	13
3	ARR	13
3	CPL	8
3	EST	13
3	CDN	13
3	ACP	13
3	RQP	13
3	RQS	13
3	SPL	13

Figure 2.2Q - ATS Messages

Excerpt from ICAO DOC 4444, Air Traffic Management (PANS-ATM) Chapter 10, Air Traffic Services Messages, Appendix 3, Field Type 13 below

A3-14 ***Air Traffic Management (PANS-ATM)***

Field Type 13 — Departure aerodrome and time

FIELD TYPE 13

Format: – | a | * | b |

SINGLE HYPHEN

(a) *Departure aerodrome*

4 LETTERS, being

the ICAO four-letter location indicator allocated to the departure aerodrome, as specified in Doc 7910, *Location Indicators*, or

ZZZZ if no ICAO location indicator has been allocated (*see Note 1*) or if the departure aerodrome is not known, or

AFIL if the flight plan has been filed in the air (*see Note 2*).

Note 1.— If ZZZZ is used, the name and location of the departure aerodrome is to be shown in the Other Information Field (see Field Type 18) if this Field Type is contained in the message.

Note 2.— If AFIL is used, the ATS unit from which supplementary flight data can be obtained is to be shown in the Other Information Field (Field Type 18).

* This field shall be terminated here in message types CPL, EST, CDN and ACP. It shall be terminated here in message type RQP if the estimated off-block time is not known.

Previous type of field or symbol	*This type of field is used in*	*Next type of field or symbol*
10	ALR	15
10	FPL	15
7	CHG	16
7	CNL	16
7	DLA	16
7	DEP	16
7	ARR	(16)** 17
10	CPL	14
7	EST	14
7	CDN	16
7	ACP	16
7	RQP	16
7	RQS	16
7	SPL	16

** Only in case of a diversionary landing

(b) *Time*

4 NUMERICS giving

the estimated off-block time (EOBT) at the aerodrome in (a) in FPL, ARR, CHG, CNL, DLA and RQS messages and in RQP message, if known, or

the actual time of departure from the aerodrome in (a) in ALR, DEP and SPL messages, or

the actual or estimated time of departure from the first point shown in the Route Field (see Field Type 15) in FPL messages derived from flight plans filed in the air, as shown by the letters AFIL in (a).

Examples: –EHAM0730
–AFIL1625

Figure 2.2R - ATS Messages

Excerpt from ICAO DOC 4444, Air Traffic Management (PANS-ATM) Chapter 10, Air Traffic Services Messages, Appendix 3, Field Type 20

Appendix 3 *A3-29*

Field Type 20 — Alerting search and rescue information

FIELD TYPE 20

Previous type of field or symbol	*This type of field is used in*	*Next type of field or symbol*
19	ALR	)

Format: – [ ] (sp) [ ] (sp) * (sp) [ ]
(*EIGHT elements in all)

This field consists of the following specified sequence of elements separated by spaces. Any information not available should be shown as "NIL" or "NOT KNOWN" and not simply omitted.

SINGLE HYPHEN

(a) *Identity of operator*

The ICAO two-letter designator of the aircraft operating agency or, if this has not been assigned, the name of the operator.

(b) *Unit which made last contact*

6 LETTERS consisting of the 4-letter ICAO location indicator followed by the 2-letter designator which together identify the ATS unit which made the last two-way contact or, if these are not available, some other description of the unit.

(c) *Time of last two-way contact*

4 NUMERICS giving the time of the last two-way contact.

(d) *Frequency of last contact*

NUMERICS as necessary giving the transmitting/receiving frequency of the last contact.

(e) *Last reported position*

The last reported position expressed in one of the data conventions of 1.6 of this Appendix followed by the time over that position.

Figure 2.2S - ATS Messages

cont…

Field Type 20 (cont.)

(f)	*Method of determining last known position*
	Plain-language text as necessary.

(g)	*Action taken by reporting unit*
	Plain-language text as necessary.

(h)	*Other pertinent information*
	Plain-language text as necessary.

Example: –USAF LGGGZAZX 1022 126.7 GN 1022
PILOT REPORT OVER NDB ATS UNITS
ATHENS FIR ALERTED NIL

Figure 2.2T - ATS Messages

s) Issues with Manual of Air Traffic Services (MATS)

i) MATS 1 PART 2 - GEN, page 2-2-1 stipulates that:

2.1.2 Controllers and other operational staff shall:

a. apply as appropriate the rules, procedures, separation minima and guidance material contained in this manual in the control of air traffic and in the provision of other air traffic service; and

b. additionally comply with directive detailed in SOIs, ROIs, and UOIs and in Operational Letters of Agreement.

2.1.3 Controllers shall not deviate from a rule or separation minima, but may however deviate from a procedure if in the opinion of the Controller the situation warrants.

2.1.4 if a situation that is not covered in this Manual arises, Controllers shall use their best judgement as to the procedure to be applied to handle the situation.

In any uneventful situations, there are specific actions that require ATC personnel to maintain a continuous watch in their respective working positions and not to rely on information from MAS ODC.

SECTION 2 – ANALYSIS

2.3 MEDICAL/HUMAN FACTORS ISSUES

2.3.1 Introduction

This section analyses general human performance issues such as the medical history, professional qualifications, training, factors related to mental and physical fatigue, crew-to-ground communications, psycho-social events, and other relevant factors.

The analysis was done based on the following sources gathered from:

1) Personal records/files of the PIC, FO and the cabin crew from MAS. These documents included the log book, certificates, licenses, medical records and any disciplinary/administrative actions;

2) Investigation details from the Polis Di Raja Malaysia (PDRM) - Royal Malaysia Police. These were statements obtained from the next of kin and relatives, doctors/care givers, co-workers, friends and acquaintances; financial records of the flight crew, CCTV recordings at KLIA and analysis of the radio transmission made between MH370 and ground Air Traffic Control;

3) Medical records from private health care facility and from MAS Medical Centre; and

4) Interviews with MAS staff and several of the next of kin of the crew.

The analysis attained from documentations, CCTV recordings and interviews were conducted ethically, based on professional assessments code of practice of the Team.

2.3.2 General Human Performance Issues

1) The flight-crew's medical background and recent activities were examined. All medical files reviewed showed no significant health-related issues. Information derived from interviews with the medical health care professionals in the MAS organisation, members of the family and some friends of the flight crew, and study of the available medical records indicate that the PIC and FO were in good health and certified fit to fly at the time of the flight.

2) The Team noted that the medical records or reports of the flight crew obtained from the MAS Medical Centre facility did not include medical records or reports from other medical facilities. In fact, the Team has found a medical record of the PIC from another private medical centre which was not recorded in the MAS Medical Centre. The records from the MAS Medical Centre as well as the records from private clinics regularly visited by both the flight crew also seemed to be mainly records related to minor ailments such as coughs and colds and may not be reflective of the complete medical record of the individuals in question.

3) Based on the available medical records, only one cabin crew member, the In-Flight Supervisor, was known to have a history of previous seizures in 2013 but was subsequently certified fit to fly. However, all the cabin crew were fit to fly at the time of the flight.

   a) All cabin crew were adequately rested before the flight based on the flying records.

   b) There is no evidence that members of the cabin crew had received any flight training, based on the '*Basic Flying Training*' and '*Aircraft Type Conversion Training'* (B777) records of the Company and records of DCA.

4) Both the PIC and FO held valid airman licenses and medical certification. They had received all the required training. It was concluded that both the PIC and FO were properly trained, licensed and qualified to conduct the flight.

5) Based on the flying records from the Scheduling Office, both the PIC and FO were within duty-time limits and therefore were adequately rested before the flight.

6) The interpersonal relationship between the PIC and FO was examined. There were no reports of any conflicts or problems between the PIC and FO prior to the flight or before the day of the flight. This is the first time the PIC and FO have flown together after the latter completed his upgraded training to the B777. The Team did not find any evidence of a strain in the relationship between the two. It was the FO's last Line Training flight before he was scheduled to be checked out. The FO's training progress was within the performance of new FOs promoted to the B777 from the smaller fleet.

2.3.3 Specific Human Factors Issues

In this section, the specific personal relationships, financial background, personal insurance coverage and benefits, past medical and medication history, as well as the recent behaviour of the PIC, FO and all the cabin crew were examined.

1) **Personal Relationships**

Information obtained from family and friends of both the PIC and FO suggested no recent changes or difficulties in personal relationships. There was nothing significant observed by the family and friends of the crew. The PIC and FO as well as the crew were not experiencing difficulties in any personal relationships.

2) **Pilot-in-Command**

The investigation into the personal and professional career revealed that the PIC had flawless safety records with a smooth career pathway to his existing position as a Type Rating Examiner on the B777 and has been well respected throughout his flying career. He was considered a leading pilot who was given privileges to be an instructor and examiner.

3) **First Officer**

The investigation into the personal and professional career revealed that the FO had a good safety record with a smooth career pathway to his existing position as a Co-pilot under training on the B777-200ER. The investigation into the FO's personal and professional history revealed no disciplinary records.

4) **Cabin Crew**

There is no evidence to suggest that any members of the cabin crew had experienced career-related incidents or mishaps resulting in major disciplinary records.

5) **Financial Background and Insurance Coverage**

Information obtained on the financial background for the PIC, FO and all the cabin crew showed no evidence of financial stresses or impending insolvency. Analysis of the bank financial statements did not reveal any incidents of unusual financial transactions.

Based on the available data, investment or trading accounts owned by the PIC were mainly inactive or dormant. The FO and cabin crew have no investment or trading accounts. Insurance coverage records were unremarkable which include generally life insurance policy, motor vehicle insurance policy, medical insurance policy and personal accident policy. There is no evidence of recent or additional insurance cover purchased by the PIC, FO or any members of the cabin crew.

6) Past medical and medication history

In the course of the investigation, it was confirmed that the PIC sustained a spinal injury as a result of a paragliding accident in January 2007. He was medically certified to have recovered from the injury, and there is no record of him being on long term medication for this, or other medical ailments. Scrutiny of his credit card transactions failed to reveal a pattern of regular purchase of over-the-counter medication of any significance, either in local or overseas pharmacies. The possibility that such medication may have been purchased by cash cannot be excluded.

The Team has further investigated the overseas over-the-counter prescriptions as there was no recorded transaction on the PIC's credit card on any medications purchased. The Team specifically investigated the possibility of mental/stress-related ailments in the PIC and concluded that there is no medical record or other documentation of the PIC having received psychiatric treatment.

Similarly, there was no documented unusual health-related issues involving the FO. Other than the Inflight Supervisor, the other members of the cabin crew have no significant health-related issues.

7) Recent Behaviour

According to family members and work associates who interacted with the PIC, FO and the cabin crew on the day of the flight and on their most recent flights, there were no behavioural signs of social isolation, change in habits or interest, self-neglect, involvement in drug or alcohol abuse. There were no significant behavioural changes observed on all the CCTV recordings for the PIC, FO and cabin crew related to the flight.

8) Overall Comments

Evidence from the medical/human factors issues showed no unusual issues on the PIC, FO and cabin crew.

2.3.4 Human Factor Aspects of Air Traffic Control Recordings

1) Voice analysis

No Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) analysis could be done as the wreckage is yet to be found. From the available information, the speech segments for the first 3 sets of audio recordings (Airway Clearance Delivery, Lumpur Ground and Lumpur Tower) were those of the FO before take-off and the 4th and 5th sets of the audio recordings (Approach Radar and Lumpur Radar) originated from the PIC after take-off.

The Team has noted nothing unusual in the conversations by the PIC and the FO with the assigned traffic Controllers. The last sentence of "*Good Night Malaysian Three Seven Zero"* was spoken by the PIC at 1719:30 UTC [0119:30 MYT].

2) Air Traffic Control Recordings

Radiotelephony recordings between the flight crew and the Air Traffic Controllers were analysed for voice recognition and it was verified that the words spoken before take-off and after take-off were that of the FO and PIC respectively. The Team has made comparison of the voice sample analysis recorded previously and found no evidence that there was any stress or anxiety detected in the conversations. It was noticed that the PIC made the same statement of "maintaining flight level three five zero' twice at 1701.17 UTC [0107.57 UTC [0107.56 MYT]. However, the Team did not find any significance of that statement spoken twice by PIC in a short interval of 6.39 minutes.

SECTION 2 – ANALYSIS

2.4 AIRWORTHINESS & MAINTENANCE AND AIRCRAFT SYSTEMS

2.4.1 Airworthiness & Maintenance

The review of the aircraft Airworthiness and Maintenance records revealed the following:

1) No current airworthiness issues were noted. There was no evidence of any pre-existing aircraft defects that would affect the safety of the flight.

2) An assessment of the Aircraft Log Book since the original issue of the Certificate of Airworthiness by the Department of Civil Aviation, Malaysia on 03 June 2002 indicated that the aircraft maintenance was carried out in accordance with the approved manufacturer's Maintenance Planning Document and in compliance with the Department of Civil Aviation Malaysia Approved Maintenance Schedule requirements. The Certificate of Airworthiness was valid at the time of the occurrence and the next Certificate of Airworthiness was due on 02 June 2014.

3) The last A1 Check was carried out on 23 February 2014 at 53,301:17 hours and 7,494 cycles. It was also noted that the last A4 Check was carried out at Malaysia Airlines Base Maintenance at KLIA, Sepang from 14 to 16 January 2014 at 52,785:37 airframe hours and 7,422 cycles respectively.

4) The right wing tip which was damaged during taxi at Pudong, Shanghai Airport on 09 August 2012 was assessed and repaired by Boeing AOG Team at Pudong, Boeing Shanghai facility from 22 September to 03 October 2012 as per MAS-RE-1209619 instructions. The Boeing repair scheme was approved under DCAM Statement of Compliance Reference Number SC/2012/081. There was no evidence of structural anomaly in the repair scheme. The repair had no bearing on the observed events on the event flight, i.e. it would not have affected any of the on-board equipment. There was a requirement, however, for damage tolerance information to be incorporated in the aircraft maintenance programme within 24 months from 02 October 2012, as stated in the FAA Form 8100-9 for the approval of the repair by the FAA Organisation Designation Authorization (ODA). This damage

tolerance information was not yet included in the maintenance programme for the aircraft at the time of the occurrence. The due date for the incorporation would be by 02 October 2014. Incorporation of the information in the maintenance programme would address any maintenance that becomes necessary as a result of the damage tolerance assessment. However, the investigation assessed that this had no effect on the occurrence flight.

5) The cabin re-configuration was approved under the FAA STC and DCAM SOC and there is no evidence of any documented deviation from stipulated design changes.

6) A review of aircraft concessions during the last year of operation revealed that Malaysia Airlines Quality Assurance Department had requested from the Department of Civil Aviation, Malaysia for a 10-day or 100-hour extension for a C1 check from 22 August to 01 September 2013. This request was approved. There were no other concessions recorded in the Aircraft Log Book.

7) A review of Malaysia Airlines Airworthiness Directives indicated that all the applicable Airworthiness Directives for mandatory compliance were complied with.

8) A review of the recent Technical Log Book entries by the flight and ground crew did not reveal any significant defects or trends.

9) A review of Malaysia Airlines list of Hard Time Components installed on the aircraft showed that the SSFDR ULB battery life was overdue at the time of the occurrence. There was no evidence of other overdue maintenance.

10) According to maintenance records, the SSFDR ULB battery expired in December 2012. There is no evidence to suggest that the SSFDR ULB battery had been replaced before the expiry date. The SSCVR ULB battery however was replaced, as scheduled, with the next expiry in June 2014. There is some extra margin in the design to account for battery life variability and ensure that the unit will meet the minimum requirement. However, once beyond the expiry date, the ULB effectiveness decreases so it may operate, for a reduced time period until it finally discharges. While there is a definite possibility that a ULB will operate past the expiry date on the device, it is not guaranteed that it will work or that it would meet the 30-day minimum requirement.

There is also limited assurance that the nature of the signal (characteristics such as frequency and power) will remain within specification when battery voltage drops below the nominal 30-day level.

Technical Log records showed that the SSFDR (together with the ULB) was replaced on the aircraft on 29 February 2008. Component installation records for the ULB showed that at the time the SSFDR was replaced on the aircraft the expiry date for the battery was December 2012.

Interviews were held with the MAS Engineering Technical records staff to determine why the ULB battery was not replaced before the expiry. It was revealed that the Engineering Maintenance System (EMS, a computer system used to track and call out maintenance) was not updated correctly when the SSFDR was replaced on 29 February 2008. The update involves 'removal' of the old unit in the system followed by 'installation' of the new unit. In this particular instance, although the old unit was 'removed', the new unit was inadvertently not recorded as 'installed' in the system. If the system was updated correctly on the installation, the next due date for removal would have been for the replacement of the ULB battery. Since the system was not updated it did not trigger the removal of the SSFDR for replacement of the ULB battery when it was due. ULB battery replacement is normally done in the workshop by routing the removed SSFDR, together with the ULB, to the workshop. This oversight was not noted until after the disappearance of MH370 when details of the ULBs were requested.

Subsequently, MAS Engineering Technical records staff carried out a fleet-wide record inspection for the ULBs to ensure all records for other aircraft were updated accordingly.

2.4.2 Emergency Locator Transmitters

The aircraft was fitted with four Emergency Locator Transmitters (ELTs) meeting the current ICAO and regulatory requirements at the time. All four ELT battery lives were within the required expiry dates. No ELT signal from 9M-MRO was reported by the responsible Search and Rescue agencies or any other aircraft. There have been reported difficulties with the transmission of ELT signals if an aircraft enters the water, such as in the case of Air France flight AF447. In these instances, the ELT does not activate, or the transmission is ineffective as a result of being submerged under water. Furthermore, the ELT itself could be damaged or, very commonly in the case of fixed ELTs, the antenna or antenna cables become disconnected or broken. This significantly hampers any search and rescue effort and may mean the aircraft location remains undetected for a considerable time. A review of ICAO accident records (refer to *Appendix 1.6D*) over the last 30 years indicates that of 173 accidents involving aircraft fitted with ELTs, only 39 cases recorded effective ELT activation.

Following the disappearance of MH370 and in line with Global Aeronautical Distress and Safety System (GADSS) recommendation an amendment to ICAO Annex 6, Part 1 has been proposed for an Automatic Deployable Flight Recorder (ADFR). The ADFR is a combination recorder fitted into a crash-protected container that would deploy from an aircraft during significant deformation of the aircraft in an accident scenario. Considering the design and deployment features of a deployable recorder, the recorder is usually fitted externally, flush with the outer skin towards the tail of the aircraft. To find a deployed ADFR, an Emergency Locator Transmitter (ELT) is integrated in the ADFR. This ELT has the added advantage to assist in locating the accident site and facilitate search and rescue efforts. In the case of a new generation ELT being fitted, the ELT will provide emergency tracking data before the impact. Furthermore, if the wreckage becomes submerged in water, the traditional ELT signal will be undetectable, but with the deployable recorder being floatable, the ELT signal would still be detectable, and the deployable recorder would be recovered quicker. As the ADFR is floatable, there is no requirement for an underwater locating device.

2.4.3 Aircraft Health Monitoring

The Maintenance Control Centre (MCC) of Malaysia Airlines did not receive any fault messages through ACARS during the event flight even up to the time the last ACARS report was transmitted. Depending on the type of failure, failure of the ACARS itself can be reported by the system. However, no such reports were received for the flight. The traffic log of maintenance messages transmitted for the last 10 flights for the aircraft indicated that the CMCS was functioning appropriately before the event flight. On an average, 11 maintenance messages, of various systems, were transmitted on each flight. A review of the maintenance history showed no evidence of a defect trend on the CMCS.

2.4.4 Aircraft Systems Analysis

The aircraft systems analysis is severely limited by the lack of available evidence. The information in this section is primarily inferred from SATCOM transmissions, aircraft system characteristics, radar data, and the absence of other communications from the aircraft for the majority of the flight.

1) Air-conditioning, Pressurisation and Oxygen

The SATCOM handshake data indicated that the aircraft was airborne for approximately 7 hours, 37 minutes (Take-off: 0042 MYT to Last SATCOM Handshake: 0819 MYT). That the aircraft flew quite some distance over a long period suggests that it flew at high altitude. Refer to the aircraft performance section in *Section 1.6.9*.

There is no evidence from the limited data available on the status of the aircraft air-conditioning and pressurisation systems during the flight. There was no Mandatory Occurrence report raised for this aircraft on pressurisation issues. A review of the Technical Log entries since the last D check in June 2010 did not reveal any defect trends in the air conditioning or the pressurisation systems. There were also no such defects reported prior to the event flight. There was an FAA Airworthiness Directive (AD) issued which made mandatory the accomplishment of Boeing Service Bulletin 777-53A0068 which addresses a crack in the fuselage skin under the SATCOM antenna adapter. This Service Bulletin was issued on 12 June 2013. A crack in the fuselage skin could lead to rapid decompression and loss of structural integrity of the aircraft. However, this AD or the Service Bulletin was not applicable to 9M-MRO due to a different configuration and location of the SATCOM antennas.

In the event of a complete pressurisation failure, however, oxygen would be available for the flight crew through the flight crew oxygen system and masks. Two cylinders located in the left side of the main equipment centre, each of 115 cubic feet (3256 litres), would be able to supply oxygen to a single person for a duration of 27 hours, or for 2 persons for a duration of 13 hours.

For the passengers, oxygen could be supplied by chemical oxygen generators located in passenger service units (PSUs). A door with an electrically operated latch keeps the masks in a box until the oxygen deployment circuit operates. The deployment circuit would operate, and the masks automatically drop from the PSUs if cabin altitude were to exceed approximately 13,500 ft. Oxygen would flow when any mask hanging from that PSU was pulled. Oxygen would be available for approximately 22 minutes. The passenger masks can be manually deployed from the cockpit by pushing the overhead panel PASSENGER OXYGEN switch to the ON position. The electrical power to the latch is supplied through a circuit breaker located in the Main Equipment Centre. It is not possible to deactivate automatic deployment of the masks from the cockpit.

There are also portable oxygen cylinders located throughout the cabin which let the flight attendants move in the aircraft when oxygen is in use. It is also a gaseous oxygen supply for medical emergencies. The cylinders are fitted with a disposable mask. 15 cylinders are located throughout the passenger cabin. Each cylinder is of 11 cubic feet (310 litres) capacity. The flow of oxygen can be controlled by an ‘Off-On’ knob which can be rotated to control the flow from 0 to 20 liters per minute.

A review was carried out of whether there could have been an oxygen leak in the crew oxygen system. A leak of oxygen is a potential source for fire to break-out. A review of the Technical Log entries since the last D check in June 2010 did not reveal any oxygen leak in the system. There had been the usual servicing of the oxygen system when the pressure had dropped from the nominal level. The Stayover check, which is carried out whenever the aircraft planned ground time exceeds 6 hours, calls for the crew oxygen pressure to be checked. It has been the practice of the airline to service the oxygen system whenever time permits, even if the pressure is above the minimum required for dispatch (310 psi at 35°C). Tech Log entries showed that the system was serviced when the pressure dropped to, on an average, 1100 psi. On 07 March 2014, prior to the last flight, the pressure was noted to be 1120 psi and serviced to 1800 psi. However, it was not possible to eliminate the possibility of an oxygen leak on the event flight.

Another potential source of fire fed by oxygen is the issue highlighted in FAA AD 2012-13-05 which made mandatory the accomplishment of Boeing Service Bulletin 777-35A0027, as highlighted in *Section 1.6.4 para. 5)*. An electrical fault or short circuit can result in electrical heating of the low pressure oxygen hoses in the flight crew oxygen system and can cause the low pressure oxygen hose to melt or burn.

This can result in smoke and/or fire in the flight compartment. This service bulletin was already accomplished on 9M-MRO on 17 January 2014 by replacing the low pressure oxygen hoses with non-conductive low pressure oxygen hoses, reducing the likelihood of this potential source of fire.

2) Autoflight

The turn after IGARI was made from a heading of about 060° to a final heading of about 240° (a change of 180°) based on recorded radar data. Simulator sessions indicated that a bank angle of at least 30° is required to accomplish a half rate turn, of 180° in 2 minutes with a Ground speed of about 470 knots. Such a turn is not possible using autopilot as the bank angle is limited up to a maximum of 25° in any of the autopilot modes, such as LNAV or HDG SEL. Using LNAV mode, the time taken to make the turn is greater than 3 minutes. At an Indicated airspeed (IAS) of 250 knots (groundspeed – GS, of 425 knots) it took 3 minutes 3 seconds while at an IAS of 220 knots (GS of 400 knots) it took 3 minutes 30 seconds. Both manoeuvres were at 35,000 ft. Refer to *Section 2.1* on a discussion on this. From the simulator sessions it is evident that the turn itself was most likely made with the autopilot disengaged.

It is unclear how the aircraft was flown for the remainder of the flight, however the aircraft made several other turns and rolled out to level flight after the turn after IGARI. The SATCOM data indicated that the aircraft was airborne for more than 7 hours suggesting that the autopilot was probably functioning, at least in the basic modes.

3) Electrical Power

As the aircraft SATCOM system was providing log-on information to the INMARSAT satellites it can be deduced that at least part of the SATCOM system had electrical power. The SATCOM system components including the Satellite Data Unit (SDU), Radio Frequency Unit (RFU), High Power Amplifier (HPA), Low Noise Amplifier/Diplexer (LNA/DIP) and the Beam Steering Unit (BSO) are powered by the 115V AC, Left Main AC bus. This bus is normally powered by the Left Engine Generator, however a failure of the generator or the power feed to it will cause the Bus Tie Breakers to close and automatically let the Right Engine Generator power the bus.

This bus can also be powered by the Auxiliary Power Unit (APU) Generator, if the APU is started manually or automatically (such as a loss of power to both engines).

The above suggests that at least one generator was operating and providing the power to the SATCOM system after power was restored at 1825 UTC following the interrupt of between 22 to 78 minutes.

SATCOM operation, especially the electronic steering of the Radio Frequency signals through the antenna to the satellite, requires the Air Data Inertial Reference Unit (ADIRU) to be functioning. The ADIRU, which is a single unit on this aircraft, is an integrated unit having internal redundancy and provides the air data and inertial reference functions. It is powered either by the Right 28 Volt DC bus, the Left 28 Volt DC bus or the hot battery bus (a direct connection to the aircraft battery). The DC busses can be powered by the respective Main AC busses (after being rectified to DC) or by automatic switching (in case of failure of the respective AC bus) by the opposite Main AC bus. The battery itself can only supply power for a short duration, so it is highly likely that the source of power for the ADIRU was one of the generators as the SATCOM system was powered for many hours.

The operation of the SATCOM not only depends on the supply of power to its own system, it also depends on the supply of power to other systems feeding it, such as the ADIRUs. This inter-dependency of operation suggests that significant parts of the aircraft electrical power system were probably functioning throughout the flight.

4) Flight Controls and Hydraulics

The primary flight control system is highly redundant, with three operating modes: normal mode, secondary mode, and direct mode. The primary flight controls are powered by redundant hydraulic sources. The hydraulic systems are pressurised from the engines and the electrical actuation systems are similarly highly redundant. The secondary flight controls, high lift devices consisting of flaps and slats, are hydraulically powered with an electrically powered backup system. It is highly likely that the primary flight controls were functional as the aircraft altered the flight path several times and maintained flight for a long duration.

5) Instrumentation

Flight instruments are required only to fly the aircraft manually. The aircraft was equipped with Standby flight instruments which operate independently of the Primary flight instruments. Operation of the autopilot is not dependent on operation of the flight instrument displays.

Due to the lack of available evidence, it was not possible to determine the extent to which the instrumentation was operable throughout the flight. However, the instrumentation system, and the system that feed information to it, are highly redundant and driven from multiple automatically-reconfigurable electrical power sources. Based on the findings that several systems (particularly ADIRS, AIMS and SATCOM) were operable for some or all of the flight, it is very likely that some or all instrumentation was available.

6) Navigation

The main systems that are relevant for consideration are the Air Data Inertial Reference System (ADIRS), the Flight Management System (FMS) and the Global Positioning System (GPS).

If the autopilot (at least the basic modes) was functional, the ADIRS must have been operating satisfactorily because an essential input to the autopilot is the aircraft attitude which is provided by the ADIRU, the main unit of the ADIRS. In addition, the SATCOM continued to transmit during the flight as evidenced by the handshakes (*Section 1.9.5*). The SATCOM was using the High Gain Antenna for tuning. This shows that the ADIRU was operable, otherwise the Low Gain Antenna (LGA) would have been used.

As for the Flight Management System, it is unclear whether the system was functioning properly throughout the flight. This system is not essential for the operation of the autopilot.

The GPS is required for position updates of the FMS. Accurate navigation is dependent on GPS inputs. However, the ADIRU can provide the navigation reference without GPS inputs, although with lesser accuracy.

7) Engines

The aircraft satellite transmission associated with the 7th arc is most likely associated with power interruptions on board the aircraft caused by fuel exhaustion (*Section 2.4.4 para. 9)*. The time of this transmission is consistent with the maximum flight times expected for the MH370 flight, based on the total weight of fuel remaining during the last ACARS transmission at 1707 UTC. It is highly likely that both the engines were operating for the aircraft to have flown for more than 7 hours with that amount of fuel on board.

The Engine Health Monitoring (EHM) system trend reports over the last 3 months which cover 'snapshot' data points gathered at take-off, climb and cruise also showed no evidence of unusual engine behaviour for both engines. Similarly, the last report (Climb report) received at 1652 UTC on 07 March 2014 (0052 MYT on 08 March 2014) and the earlier Take-off report, do not show any unusual engine behaviour. Furthermore, there were no fault messages transmitted by the CMCS to indicate any engine abnormalities, before the ACARS last transmission.

8) Fuel Systems

The fuel systems were most probably functioning satisfactorily as the performance of the engines was dependent on this. It is unlikely that there were any problems in these based on the premise that the aircraft most likely flew to fuel exhaustion, as explained in *Section 2.4.4 para. 9)*.

9) Auxiliary Power Unit

The operation of the Auxiliary Power Unit (APU) during the majority of the flight is uncertain although it is possible that it started up automatically (as it should) after both engines shutdown due to fuel exhaustion at the end of the flight. This start-up and power-up of the electrical buses most likely caused the 7th and last, aircraft initiated SATCOM handshake.

Performance calculations indicate the possibility that the aircraft would have reached fuel exhaustion at, or before the time of the 7th handshake. After a single engine shutdown, automatic switching of the electrical tie breakers would ensure the Left and the Right Main busses and the Left and Right Transfer busses were still powered by the remaining generator driven by the running engine. After the shutdown of the second engine following fuel exhaustion, the Main busses and the Transfer busses would have de-energised as there would be no generators powering these busses. An electronic logic in the APU starting system would automatically start the APU, if the aircraft was in the air, and both the Left and Right Transfer busses were not powered. As the fuel inlet for the APU is below that of the engines (left engine main fuel inlet in the left tank) the APU can start up and run for about 14 minutes even though the aircraft engines themselves are exhausted of fuel from the fuel tanks as the difference in the fuel intake levels would provide about 30 pounds of fuel. It would take about 1 minute for the APU to start up and power the busses and once powered, the Satellite Data Unit (SDU) of the SATCOM would take approximately another 1 minute to initiate the 'handshake', which would have been the 7th and last SATCOM handshake. Both the APU start up and the initialisation of the handshake by the SDU would have happened within the 14 minutes of running time available from the 30 pounds of fuel, after which the APU would have shut down due to its own fuel exhaustion.

10) Communications

The aircraft was fitted with many communication systems, available to the flight crew. Among them were the High Frequency (HF) system, the Very High Frequency (VHF) system, the Air Traffic Control system including the Mode S Transponder, the ACARs and the SATCOM. The SATCOM phone in the cabin was available for the cabin crew. Despite the availability of all these systems no communications were received from the aircraft after the last communication at 1719:30 UTC, 07 March 2014 (0119:30 MYT on 08 March 2014) except for the 'handshakes' received from the SATCOM system.

a) High Frequency System

Communication with ATC after take-off is normally through the VHF. The HF system is for communication with ground stations or other aircraft during long overwater flights. There was no evidence to indicate that the HF systems (Left or Right) were used prior to the aircraft's last communication at 1719:30 UTC on 07 March 2014. This communication was through VHF. There was no message received from the aircraft to report on a HF system failure or system technical error prior to the last voice or ACARS communication. There was also no recent defect trend on the HF systems.

b) Very High Frequency System

The aircraft VHF system was operating satisfactorily as evidenced by the communication by the flight crew to ATC up to the last communication at 1719:30 UTC, 07 March 2014 (0119:30 MYT, 08 March 2014). There were three independent VHF communication systems on the aircraft. The crew normal procedure is to use the Left VHF for communications. There was no message received from the aircraft to report on the VHF system failure or system technical error prior to the last voice or ACARS communication. There was also no recent defect trend on the VHF systems.

c) Air Traffic Control/Mode S Transponder System

The aircraft transponder was operating satisfactorily up to the time it was lost on the ATC radar screen at 1720.36 UTC, 07 March 2014 (0120:36 MYT, 08 March 2014). There was no message received from the aircraft to report a system failure prior to the last voice or ACARS communication. The crew procedure for normal operations is to select the left system on the control panel so the left system was likely in use. Failure of the system will be annunciated in the cockpit so that the crew can select the operating system.

The Left ATC/Mode S transponder gets 115V AC power from the AC Standby bus. The Right ATC/Mode S transponder gets 115V AC power from the Right AC Transfer bus. The dual transponder panel gets 115V AC power from the AC Standby bus. The two transponders are powered by highly reconfigurable AC buses; the left one can be powered by the battery if the left AC bus is unavailable (the AC Standby bus can be powered by the left Transfer bus or the battery), and the AC Transfer busses also have their alternate sources (the Main AC busses). It is likely that the Right Main AC bus was available because otherwise the ADIRU would have lost alignment (which it did not). It is likely that the power sources for one or both transponders were available.

This system can be deactivated (turned OFF) by pulling the circuit breakers located at the P11 overhead circuit breaker panel in the cockpit or by selecting the Transponder Mode

Selector (Transponder Panel) to "STBY" position. Selecting the Mode Selector to "STBY" will deactivate both the transponders.

d) Aircraft Communications Addressing and Reporting System

The ACARS communicates through either the VHF or the SATCOM systems. The ACARS datalink connects to the Satellite Data Unit (SDU) of the SATCOM system and the Center and Right VHF Communication Transceivers of the VHF systems. The Center VHF exchanges data with the ACARS modem in the Communications Core Processor Module (CPM/Comm) of the Left AIMS cabinet. The right VHF exchanges data with the ACARS modem in the CPM/Comm of the Right AIMS cabinet. The ACARS does not interface with the Left VHF Transceiver.

For the ACARS operation the Data Communication Management Function (DCMF) of the AIMS uses the voice/data select to set the VHF Communication Transceiver to the data signal mode. At power-up, the DCMF sets the Center VHF Communication Transceiver to the data signal mode. If the Center VHF Communication Transceiver fails, or voice is selected manually by the flight crew, the DCMF selects SATCOM for data transmissions. If SATCOM fails, the DCMF selects the Right VHF Communication Transceiver for data transmissions. The Left VHF Communication Transceiver is voice only. On the event flight, voice was selected for the Center VHF on the ground which resulted in the ACARS using SATCOM for the data transmissions, as shown in the SATCOM Ground Station Logs (refer to *Section 1.9.4*).

As the ACARS function is part of the AIMS there is no direct way of removing electrical power from the ACARS. This would require removing power to the AIMS which would disable many other systems as the AIMS manages data for several integrated avionics systems. However, it is possible to deactivate the ACARS downlink function from the ACARS Manager page in the Communications main menu on the selected Multifunction Display (MFD) in the cockpit. However, this will not affect the SATCOM handshakes. The COMM display switch, located on the display select panel, displays the communications main menu on the selected MFD. The

ACARS Manager page allows the flight crew to select/deselect VHF or SATCOM transmission of data (*Figure 2.4A* below). ACARS is set to auto mode (both boxes selected) at power-up or during a manual data communication system reset. Normally, this permits ACARS to automatically use VHF or SATCOM (if VHF is unavailable). If both boxes are deselected, ACARS loses the capability to send downlink messages, but can receive and display uplink messages.

Once deselected, a power interruption, will not cause the ACARS to be set to auto mode (both the VHF and SATCOM boxes selected) again. For the ACARS to be set to auto mode, either a data communication system reset or a power-up is done. The system does an automatic data link system reset 10 minutes after last engine shutdown and first passenger door open. This would explain why the power resumption at 1825 UTC following the interruption (*Section 1.9.5 para. 4*) did not activate the ACARS downlink again (with the assumption that both the VHF and SATCOM boxes were deselected).

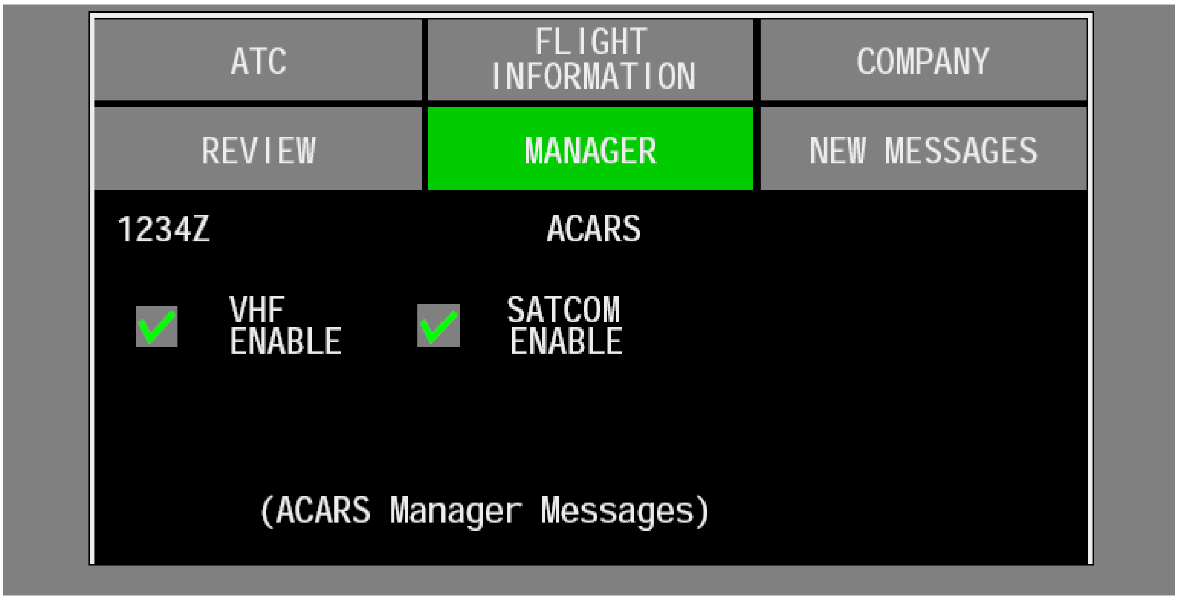

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Figure 2.4A - ACARS Manager Page on MFD

The last position report transmitted via ACARS was at 1707:29 UTC, 07 March 2014 (0107:29 MYT, 08 March 2014). Parameters recorded (*Table 2.3A*) were as follows:

Greenwich Mean Time (GMT)	1706:43 UTC
Altitude (ALT)	35004 feet
Calibrated Airspeed (CAS)	278.4 knots
MACH	0.821 Mach
Total Air Temperature (TAT)	-13.1° C
Static Air Temperature (SAT)	-43.8° C
Latitude (LAT)	5.299
Longitude (LONG)	102.713
Gross Weight (GWT)	480,600 lb
Total Remaining Fuel Weight (TOTFW)	43,800 kg
Wind Direction (WINDIR)	70.0
Wind Speed (WINDSP)	17.13
True Heading (THDG)	26.7

Table 2.4A - Last Position Report from ACARS

All programmed communications via ACARS prior to 1707:29 UTC were working satisfactorily.

After this last automatic ACARS transmission over the SATCOM, either the ACARS was turned off or the AIMS had a fault that prevented ACARS transmissions while certain other functions such as inertial data forwarding did not appear to be significantly affected.

e) Satellite Communication System

Refer to *Section 2.5* for the detailed analysis of SATCOM.

11) Airplane Information Management System

The Airplane Information Management System (AIMS) is designed with several redundancies to be failure tolerant. The system consists of two cabinets performing almost identical operations. The signal outputs of these cabinets are fed onto common busses which are shared by the various systems. These two cabinets are also isolated in location, the Left AIMs is located in the forward rack of the Main Equipment Centre (MEC) while the Right AIMS is located in the rear rack of the MEC.

The AIMS cabinets also receive electrical power from different busses. The Left AIMS cabinet gets electrical power from the 28V

DC Capt Flight Instrument bus and the 28V DC F/O Flight Instrument bus. The Right AIMS cabinet gets electrical power from the 28V DC Left bus and the 28V DC Right bus. Each cabinet receives the power from four 28V DC circuit breakers in the overhead circuit breaker panel. The four 28V DC bus inputs, known as power 1 through power 4 enter the cabinets through different routings. Power 1 and power 2, known as left power, enter the cabinet through a connector on the left side of the cabinet. Power 3 and power 4, known as right power, enter the cabinet through a connector on the right side of the cabinet.

Each AIMS cabinet has four Input/Output modules (IOM) and four Core Processor Modules (CPM). These are Line Replaceable Modules (LRM). The IOM transfers data between the software functions in the AIMS CPMs and external signal sources. The CPMs supply the software and hardware to do the calculations for several avionic systems. The software is called functions. To keep a necessary separation between the functions, each function is partitioned. The partitions permit multiple functions to use the same hardware and be in the same CPM. Each LRM receives power from four sources, two for main power and two for monitor power. The main circuitry uses the main power. Special circuits that monitor the condition of the power supply in the LRM use the monitor power. The two main and two monitor sources of power for each LRM come from different power sources. Each LRM must have at least one main and one monitor power input to operate. The loss of any one of the four power buses to the backplane power bus or to any one LRM has no effect on the function of the LRMs. The loss of two power inputs from the same side of the cabinet, left or right, has no effect on the function of the LRMs. The loss of one power input from the left side and one power input from the right side results in the loss of function in four LRMs. The loss of three or four of the power buses to the cabinet chassis power backplane results in the loss of function of all the LRMs.

Each AIMS cabinet also receives power through one hot battery bus circuit breaker in the standby power management panel. The connection to the hot battery bus keeps the LRMs internal memories active. The hot battery bus also makes the AIMS cabinet less likely to have faults due to power transients.

Given the preceding arrangement of dual and distant location of the AIMS cabinets, independent and multiple power sources and separation of the computing functions the likelihood of failure of the AIMS operation is remote. Furthermore, operation of the SATCOM is reliant on satisfactory operation of the AIMS. Regular SATCOM 'handshakes' were present, till the 7th and last handshake at 0019 UTC. This indicates that the AIMS, or at least part of it, was operational.

2.4.5 Summary

From the foregoing discussion it can be generally deduced that there is no evidence to suggest that a malfunction had caused the aircraft to divert from its filed flight plan route. The aircraft's maintenance history and events prior to the last flight do not show any issues that could have contributed and resulted in the deviation and subsequent changes in the flight path. Although it cannot be conclusively ruled out that an aircraft or system malfunction was a cause, based on the limited evidence available, it is more likely that the loss of communication (VHF and HF communications, ACARS, SATCOM and Transponder) prior to the diversion is due to the systems being manually turned off or power interrupted to them or additionally in the case of VHF and HF, not used, whether with intent or otherwise.

Similarly, the recorded changes in the aircraft flight path following waypoint IGARI, heading back across peninsular Malaysia, turning south of Penang to the north-west and a subsequent turn towards the Southern Indian Ocean are difficult to attribute to any specific aircraft system failures. It is more likely that such manoeuvres are due to the systems being manipulated.

The analysis of the relevant aircraft systems taking into account the route followed by the aircraft and the height at which it flew, constrained by its performance and range capability, does not suggest a mechanical problem with the aircraft.

SECTION 2 – ANALYSIS

2.5 SATELLITE COMMUNICATIONS ANALYSIS

2.5.1 Summary of Key Observations of the SATCOM Ground Station Logs

The key observations of the SATCOM Ground Station Logs, with an assessment, are summarised below:

1) Prior to take-off, the SATCOM Logged On (normally) a number of times, the last time being at 1600, when it sent a valid Flight ID to the Ground Earth Station (GES). The SATCOM link was available for both voice and data (known as Log-On Class 3).

2) After take-off, the In-Flight Entertainment System (IFE) Short Messaging System (SMS) e-mail application sent a normal beginning of flight message at 1642 (containing the correct Airborne Earth Station (AES ID), Flight ID "MAS370", origin airport "WMKK", and destination airport "ZBAA"), indicating that the IFE was receiving the valid Flight ID, origin airport and destination airport from Airplane Integrated Management System (AIMS) and the ICAO (AES) ID from the Satellite Data Unit (SDU) at this time.

3) The SATCOM link was available for most of the flight, excluding periods leading up to 1825 on 07 March 2014 and 0019 on 08 March 2014.

4) When the SATCOM link was re-established at the above times, no Flight ID was present. This implies that a valid Flight ID probably stopped being sent to SATCOM at some time between 1642 (when the IFE reported the correct Flight ID) and 1825 (when the SATCOM Logged On with no Flight ID) on 07 March 2014. The possible reasons for the link losses and the subsequent Log-Ons that took place at 1825 and 0019 have been investigated and are detailed in tables in *Section 2.5.2.* There are many quite complicated scenarios that could have caused the 1825 Log-On. However, the most likely reason is a lengthy power interrupt to the SATCOM. The most likely reason for the 0019 Log-On was also a power interrupt to the SATCOM.

5) During the two in-flight Log-Ons at 1825 and 0019, the GES recorded abnormal frequency offsets for four burst transmissions from the SATCOM. After extensive analysis, the following explanations have emerged.

The 1825 Log-On Request had a non-zero BER and could therefore have been logged at the Ground station with a BFO measurement error suggesting that the BFO figure may not be reliable.

a) 1825 Log-On Acknowledge - Most likely due to the power-on drift of the SDU Oven Controlled Crystal Oscillator (OCXO), thus endorsing the belief that the 1825 Log-On was preceded by a lengthy power interrupt.

b) 0019 Log-On Request - Could have been due to uncompensated vertical velocity, indicating that the aircraft was likely to be descending at this time. Alternatively, it could have been due to the OCXO warm up drift, or it could have been due to a combination of uncompensated vertical velocity and OCXO warm up drift.

c) 0019 Log-On Acknowledge - Could have been due to uncompensated vertical velocity, indicating that the aircraft was likely to be descending at this time. Alternatively, it could have been due to the OCXO warm up drift, or it could have been due to a combination of uncompensated vertical velocity and OCXO warm up drift.

d) It has not been possible to attribute specific correction values to the 1825 Log-On Acknowledge and 0019 Log-on Request and Log-On Acknowledge BFOs, so it was excluded from the Doppler calculations undertaken by the Aircraft Flight Path/Performance Subgroup. In the case of the 1825 Log-On Acknowledge, the following subsequent bursts were used instead, as the frequency is more stable at these times:

   i) 1828:05.904 Data-3 R-Channel burst.

   ii) 1828:14.905 Data-3 R-Channel burst.

6) There is no indication of the SATCOM link being manually Logged Off from the cockpit (via a Multi-function Control Display Unit [MCDU]). Such activity would have been captured in the GES logs, but it was not.

7) No Data-2 Aircraft Communications Addressing and Reporting System (ACARS) traffic was observed after 1707 on 07 March 2014.

8) The IFE equipment set up two ground connections over SATCOM (for the SMS e-mail application and Built-In Test Equipment (BITE) application) after the SATCOM re-established the link at 1825 on 07 March 2014 (normal), but not after the SATCOM re-established the link at 0019 on 08 March 2014 (abnormal). In the 0019 case, it is possible that the IFE was no longer powered, or failed, or that the IFE and/or the SATCOM became inoperative before the connections could be set up. At no time during the flight was any user data sent over the link by means of the SMS/e-mail application.

9) Two Ground-to-Air Telephony Calls were placed to the cockpit from the MAS Airline Operations Centre at Airline Operational Communications (AOC) Q10 priority level at 1839 and at 2313 on 07 March 2014. Neither of the calls was answered.

10) The SATCOM responded normally to a series of roughly hourly Log-On Interrogations from the Perth GES, up to and including a Log-On Interrogation at 0011 on 08 March 2014. The two unanswered ground to air calls at 1839 and 2313 reset the Perth GES inactivity timer and hence the Log-On Interrogations were not always hourly.

11) The SATCOM transmissions during the two in-flight Log-Ons and five Log-On Interrogations form the seven ‘handshakes’ that have been used by the Flight Path/Performance Subgroup to calculate the seven geographical ‘arcs’.

12) The last transmission received from the SATCOM occurred at 0019 on 08 March 2014 and the SATCOM failed to respond to a series of three Log-On interrogations starting at 0115 on 08 March 2014. This implies that the SATCOM probably became inoperative at sometime between 0019 and 0115 on 08 March 2014.

2.5.2 Possible Reasons for the 1825 and 0019 Log-On Events and Preceding Link Losses

1) First In-Flight Log-On at 1825 on 07 March 2014

Flight ID Status Change Description	Log-On Reason	Likelihood	Comments
Flight ID stopped being received from AIMS, or being received, but with the Sign Status Matrix (SSM) field not set to Normal Operation.	Power Interrupt	Medium	CBs are not readily accessible, but could have been due to power interrupt.
	Sysfail (software fail)	Very low	Sysfail is a very rare event and usually results in only a few minutes loss of link.
	Loss of Minop[37] or Loss of Link	Not possible	Loss of Minop or link would have resulted in the original Flight ID being sent to the GES at Log-On.
Flight ID received from AIMS, but with null value (zeros) and Sign Status Matrix (SSM) field set to Normal Operation	Power Interrupt	Low	Flight ID would have to have transitioned to null value whilst the SDU was not powered.
	Sysfail (software fail)	Very low	Flight ID would have to have transitioned to null value whilst the SDU was in Sysfail (which is a rare event in itself).
	Loss of Minop or Loss of Link	Low	Flight ID would have to have been cleared whilst the SDU was in loss of Minop or experiencing loss of link (duration at least 22 minutes). Otherwise a Log-On Renewal would have occurred and the GES log shows that a Log-On renewal did not occur.
Flight ID manually cleared via the MCDU	Power Interrupt or Sysfail (software fail)	Not possible	SDU needs to be operational to accept null Flight ID via an MCDU.
	Loss of Minop or Loss of Link	Low	Flight ID would have to have been manually cleared whilst the SDU was in loss of Minop or experiencing loss of link (duration between 22 and 78 minutes). Otherwise a Log-On Renewal would have occurred and the GES log shows that a Log-On Renewal did not occur.

Table 2.5A - Possible Reasons for the 1825 Log-On Events and Preceding Link Losses

From the above table, the most likely reason for the 1825 Log-On is a power interrupt.

[37] Loss of Minop - Is the inability of the AES to Log-On, because of one or more missing or failed resources, (e.g. equipment BITE failure).

2) Second In-Flight Log-On at 0019 on 08 March 2014

Log-On Reason	Likelihood	Comments
Power Interrupt	Medium	The SATCOM CBs are not readily accessible and are therefore unlikely to have been cycled. However, given that MH370 could have been low on fuel at this time, some form of generator transfer may have occurred, resulting in a SATCOM power interrupt.
Sysfail (software fail)	Very low	Sysfail is a very rare event.
Loss of Minop	Low	Loss of Minop - Normally a very low likelihood, but given that MH370 could have been low on fuel at this time, some form of generator-related abnormal operation of a peripheral system (e.g. AIMS) may have occurred.
Loss of Link	Low	Loss of Link would have prompted a new Log-On attempt via the Low Gain Antenna (LGA) subsystem. From the GES records, the subsequent Log-On is known to have been via the High Gain Antenna (HGA) subsystem, so for loss of link to be the Log-On reason, both the HGA and LGA subsystems would have had to have failed to close the link for a while. This is only likely in the case of an abnormal aircraft attitude, but given that MH370 could have been low on fuel at this time, this is a plausible reason.

Table 2.5B - Possible Reasons for the 0019 Log-On Events and Preceding Link Losses

From the above table, the most likely reason for the 0019 Log-On is a power interrupt.

Note:

The above table does not include the 'Flight ID Status Change Description' column that appears in the previous table, as there is no change of Flight ID Status for this second in-flight Log-On.

3) Preceding Link Losses

Although the link loss that is believed to have preceded the 1825 Log-On is most likely to have been due to a power interrupt, for completeness, other possible reasons for the link loss are considered in the following table (*Table 2.5C*).

Link Loss Reason	Likelihood	Comments
Automatic Satellite/GES Handover	Very low	Had the SDU initiated a handover, a Log-Off Request should have been recorded in the GES log. No such request was recorded.
Manual Log-Off, via the MCDU	Very low	Had a manual Log-Off been initiated via the MCDU, a Log-Off Request should have been recorded in the GES log. No such request was recorded.

Table 2.5C – Other Reasons for the Link Loss

The above table confirms that the link loss that is believed to have preceded the 1825 Log-On was not due to Satellite/GES handover or manual intervention via the MCDU.

2.5.3 Summary Assessment of Doppler for 1825 and 0019 Log-On Events

1) During each of the two in-flight Log-Ons that occurred during flight MH370, the GES recorded abnormal frequency offsets for the SATCOM transmissions. This is in contrast with the 'normal' Log-On behaviour.

2) *Table 1.9D* in *Section 1.9.5* shows the frequencies of these Log-On bursts, as measured at the GES, plus differences from assumed reference frequencies. The table also shows the very high delta frequencies between the respective Log-On Request and Log-On Acknowledge bursts.

3) The following graph *(Figure 2.5A)* shows the delta frequencies between pairs of Log-On Request and Log-On Acknowledge bursts for over one hundred Log-Ons of the SATCOM on-board 9M-MRO, up to and including the two during flight MH370. In every case prior to MH370 the delta frequencies were fairly small. Only the last two pairs of transmissions (the 1825 and 0019 Log-Ons) show significant deltas. Note that for ease of display, only the magnitude is shown for the two MH370 Log-On frequency deltas.

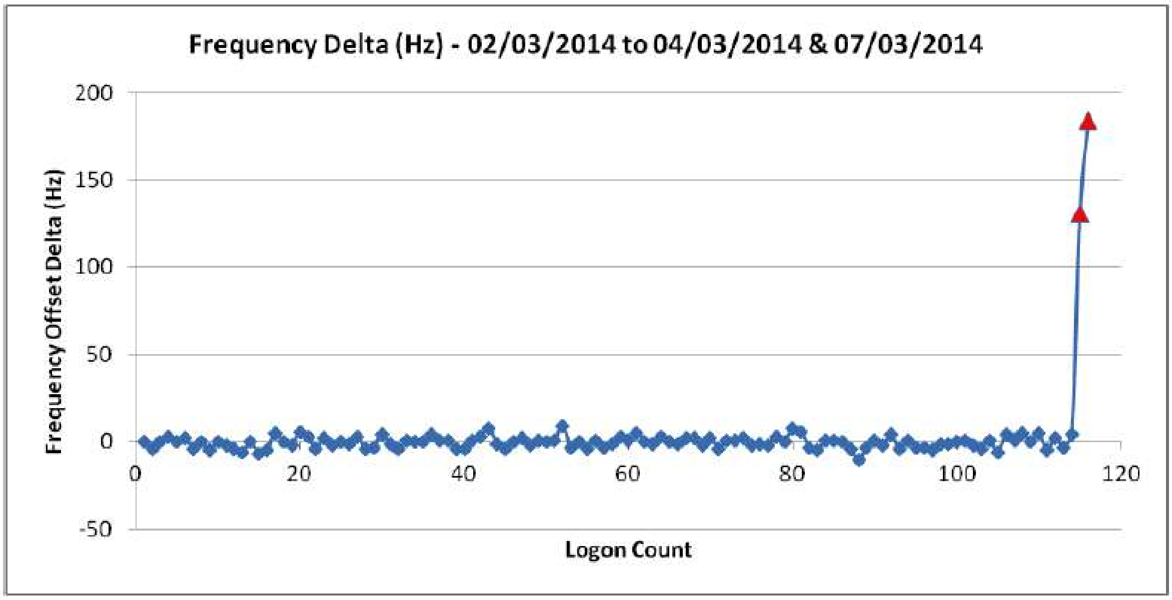


Figure 2.5A – Delta Frequencies between Pairs of Log-On Request and Log-On Acknowledge

4) From the Perth GES logs, the AES is known to have Logged-On as Class 3 (Voice & Packet Data). In order to have done so, the SDU must have been receiving valid Air Data Inertial Reference Unit (ADIRU) data from AIMS. In this case, the AES would apply open loop Doppler compensation, whereby it uses the ADIRU data in order to calculate the transmit frequency Doppler offset.

5) An OCXO provides a stable reference frequency for the SDU Radio Frequency (RF) transmit and receive circuits and also for

SDU modem timing. Within the OCXO, a regulated oven keeps the crystal at an almost constant temperature if the ambient temperature in the crown area is between the ranges -55^{0}C up to above +70^{0}C. The oven also contains extra electrical regulation and isolation to ensure frequency accuracy and stability. The OCXO includes an oven ready flag, which triggers the Log-On initiation when the OCXO reaches its operating temperature. Extensive laboratory testing has revealed that during warm up, the OCXO frequency may vary non-linearly with time, but then settles with almost negligible variation. At power-on, the OCXO can exhibit either a rising or falling frequency gradient, before decaying over time to its normal steady state value. The testing has indicated that reasonable stability (within 2Hz/minute) is typically reached by around five minutes after an initial peak or overshoot. The testing has also shown that there can still be a significant frequency offset at the time that the oven ready flag initiates the Log-On process, so the Log-On request, Log-On Acknowledge and subsequent data bursts can all exhibit significant frequency offsets.

6) These frequency offsets can be seen in the plot (*Figure 2.5B)* below, for a 9M-MRO SATCOM Log-On (believed to have taken place after a lengthy power down), at 1250 on 07 March, whilst the aircraft was on the ground at Kuala Lumpur, prior to the departure of MH370. The frequency has stabilised to a value of around 350Hz, within three minutes of the Log-On Request.

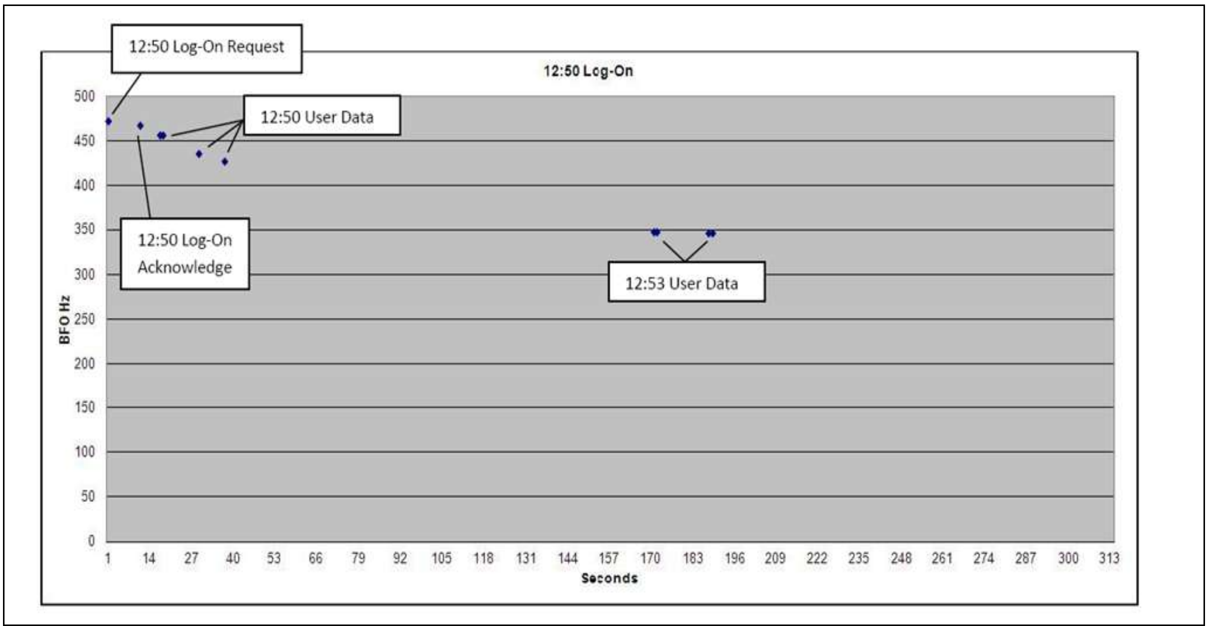


Figure 2.5B - SATCOM Log-On Frequency Offsets at 1250, 07 March 2014

7) These frequency offsets can also be seen in the plot (*Figure 2.5C)* below for the MH370 1825 Log-On. As with the 1250 Log-On, the frequency has stabilised within three minutes of the Log-On Request, this time at around 150Hz.

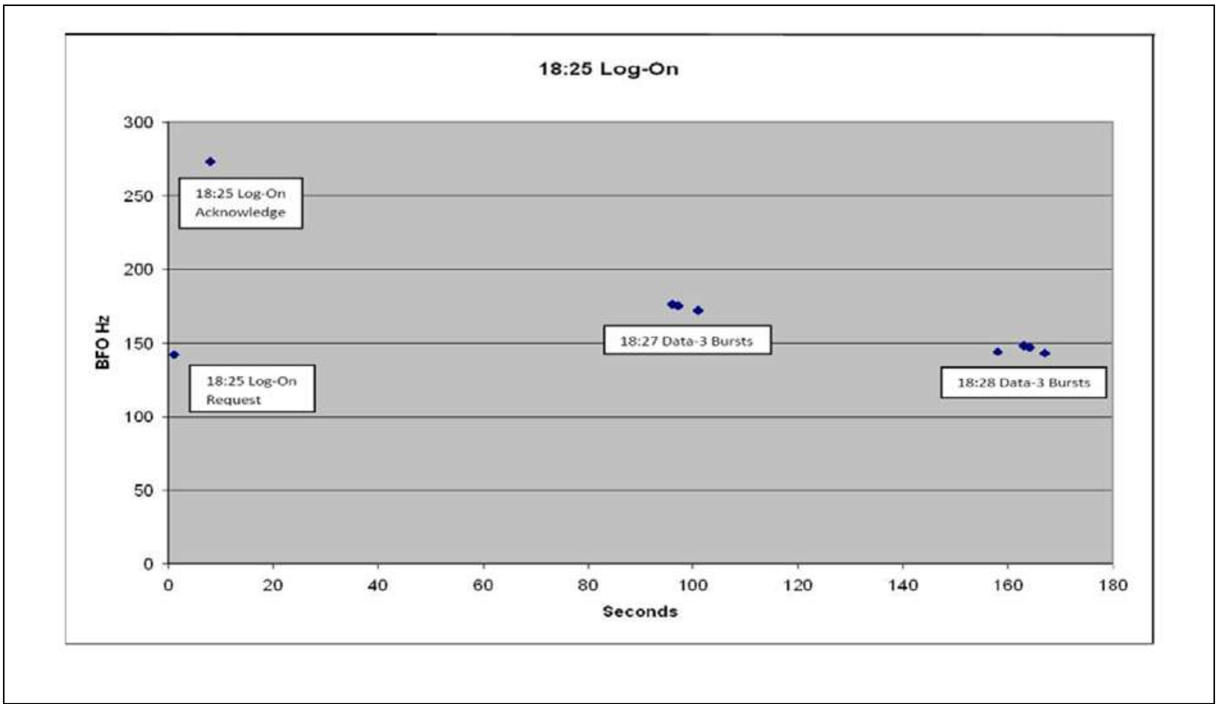


Figure 2.5C - SATCOM Log-On Frequency Offsets at 1825, 07 March 2014

8) The 1825 Log-On Acknowledge and the subsequent Data-3 transmissions exhibit a frequency offset, which decays to the steady state value. This frequency decay endorses the belief that the SATCOM had been powered down prior to the 1825 Log-On.

9) The 1825 Log-On Request does not exhibit the frequency offset decay though. However, it is possible that the OCXO frequency was rising at this time, prior to decaying to its steady state value. It is noted that the 1825 Log-On Request was received at the GES with a low Received Carrier/Noise Density Ratio (C/No) and a channel Bit-Error-Rate (BER) of 5 and could therefore have been logged at the Ground station with a BFO measurement error suggesting that the BFO figure may not be reliable. Non-zero channel BER transmissions are not uncommon for a satellite link. The C/No (and hence channel BER) can be impacted by the gain of the SATCOM antenna and also atmospheric effects, as well as interference due to collisions with a (lower power) burst from another aircraft.

10) In the seven days leading up to flight MH370, 235 out of 6803 (3%) of 9M-MRO SATCOM Class 3 transmissions (via HGA) were received at a GES with a non-zero channel BER and during flight MH370, 5 out of 112 (4%) of transmissions were received at a GES with a non-zero channel BER. So, the MH370 SATCOM performance from a channel BER perspective appears to have been normal.

11) The plot *(Figure 2.5D)* below shows a series of MH370 Log-On Interrogation transmissions, which steadily rise in frequency (due to the satellite ephemeris). However, the 0019 Log-On Request and Log-On Acknowledge transmissions diverge from the steady state slope.

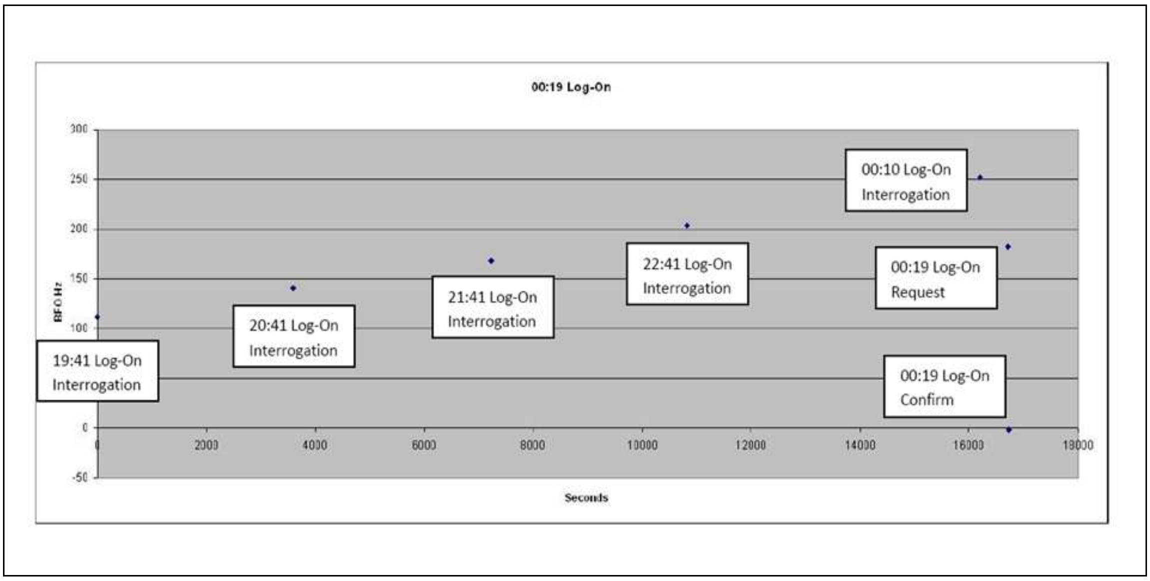


Figure 2.5D - Log-On Interrogation Transmissions

12) For the 0019 BFOs, the following possible error contributions are considered:

a) GES Measurement Errors - There is only evidence to suggest a significant GES measurement error in the case of a burst that is received at the GES with a non-zero channel BER, as in the case of the 1825 Log-On Request. This was not the case with the 0019 BFOs, so it can be discounted.

b) SDU OCXO Reference Error – OCXO stability has been measured over both temperature (circa -0.65Hz/deg. C) and time (as described above). The OCXO double inflection warm up drift could explain at least part of the 0019 Log-On Request and Log-On Acknowledge frequency offsets.

c) Satellite Doppler Towards SDU and GES - Doppler frequency offset due to the relative movement of the satellite could not account for the >100Hz frequency shift in the <10 seconds between the 0019 Log-On Request and the Log-On Acknowledge bursts.

d) Doppler Error due to ADIRU Drift - If the aircraft ADIRU is assumed to have a maximum drift of 2kts (1m/s), then the worst case Doppler offset is 16Hz, significantly smaller magnitude than the >100Hz frequency shift in the <10 seconds between the 0019 Log-On Request and the Log-On Acknowledge bursts.

e) Doppler due to erroneous ADIRU Data - From a SATCOM perspective, the SDU will not use navigation data unless the Sign Status Matrix (SSM) for every one of the required ARINC 429 words (Latitude, Longitude, Groundspeed, Track, Pitch, Roll and Heading) is set to Normal Operation. It is "extremely improbable" that an ADIRU will send erroneous data with the SSM set to normal. In this case, we can conclude that the abnormal frequency offsets are extremely unlikely to be as a result of the SDU receiving or acting upon erroneous navigation data from an ADIRU.

f) Uncompensated Vertical Velocity - The SATCOM SDU does not consider vertical velocity in its Doppler calculation. It has been calculated that a vertical velocity of +100ft/min causes about a +2Hz change in the Doppler shift. Therefore, under normal circumstances, only a small frequency error results from the uncompensated vertical velocity. For example, an ascent or descent rate of 2000ft/minute would cause a 40Hz offset. In the case of MH370, a significant vertical velocity could explain at least part of the 0019 Log-On Request and Log-On Acknowledge frequency offsets.

13) In summary, the abnormal BFOs for the 1825 and 0019 Log-Ons can be explained as follows:

    a) The 1825 Log-On Acknowledge - Most likely due to the power-on drift of the OCXO.

    b) 0019 Log-On Request and Log-On Acknowledge - Could have been due to uncompensated vertical velocity, indicating that the aircraft was likely to be descending at this time. Alternatively, it could have been due to the OCXO warm up drift, or it could have been due to a combination of uncompensated vertical velocity and OCXO warm up drift.

14) It has not been possible to attribute specific correction values to the 1825 Log-On Acknowledge and 0019 Log-on Request and Log-On Acknowledge BFOs, so it was excluded from the Doppler calculations undertaken by the Aircraft Flight Path/Performance Subgroup. In the case of the 1825 Log-On Acknowledge, the following subsequent bursts were used instead, as the frequency is more stable at these times:

    - 1828:05.904 Data-3 R-Channel burst.
    - 1828:14.905 Data-3 R-Channel burst.

SECTION 2 – ANALYSIS

2.6 WRECKAGE AND IMPACT INFORMATION

2.6.1 Debris Considered for Detailed Examination

After the completion of the underwater search no wreckage belonging to MH370 was found. However, a number of debris were washed ashore near and onto the coast of south east Africa. Only the right flaperon, part of the right outboard flap and a section of the left outboard flap were confirmed to be from MH370. So far, 7 other pieces were also determined to be *almost certain* from MH370. To date, 27 items were considered significant for evaluation and the table below lists them and the status.

Ref.	Debris	Status
Item 1	Right Flaperon	*Confirmed*
Item 2	Right Wing No. 7 Flap Support Fairing	*Almost certain*
Item 3	Right Horizontal Stabiliser panel piece	*Almost certain*
Item 4	Engine Nose Cowl	*Almost certain*
Item 5	Door R1 Stowage Closet	*Almost certain*
Item 6	Right Hand Engine Fan Cowling	*Almost certain*
Item 7	Wing Body Fairing	*Likely*
Item 8	No. 1 Flap Support Fairing Tail Cone	*Highly Likely*
Item 9	Left Wing Trailing Edge Panel	*Highly Likely*
Item 10	Left Outboard Aft Flap Section	*Confirmed*
Item 11	Seat Back Trim Panel Encasing IFE Monitor	*Highly Likely*
Item 12	Bottom Panel of Wing or Horizontal Stabilizer	*Likely*
Item 13	Unidentified Part	*Not Identifiable*
Item 14	Unidentified Part	*Not Identifiable*
Item 15	Right Wing Trailing Edge Panel	*Highly Likely*
Item 16	Cabin Interior Panel	*Almost certain*
Item 17	Unidentified Part	*Not Identifiable*
Item 18	Right Forward Nose Landing Gear Door	*Highly Likely*
Item 19	Right Outboard Flap	*Confirmed*
Item 20	Right Aft Wing to Body Fairing	*Highly Likely*
Item 21	Unidentified Part	*Not Identifiable*
Item 22	Right Vertical Stabilizer Panel	*Almost Certain*
Item 23	Unidentified Part	*Not Identifiable*
Item 24	Unidentified Part	*Not Identifiable*
Item 25	Unidentified Part	*Not Identifiable*
Item 26	Right Aileron	*Highly Likely*
Item 27	Right Wing No. 7 Flap Support Fairing	*Highly Likely*

Table 2.6A - List of Debris Found and Considered for Detailed Examination

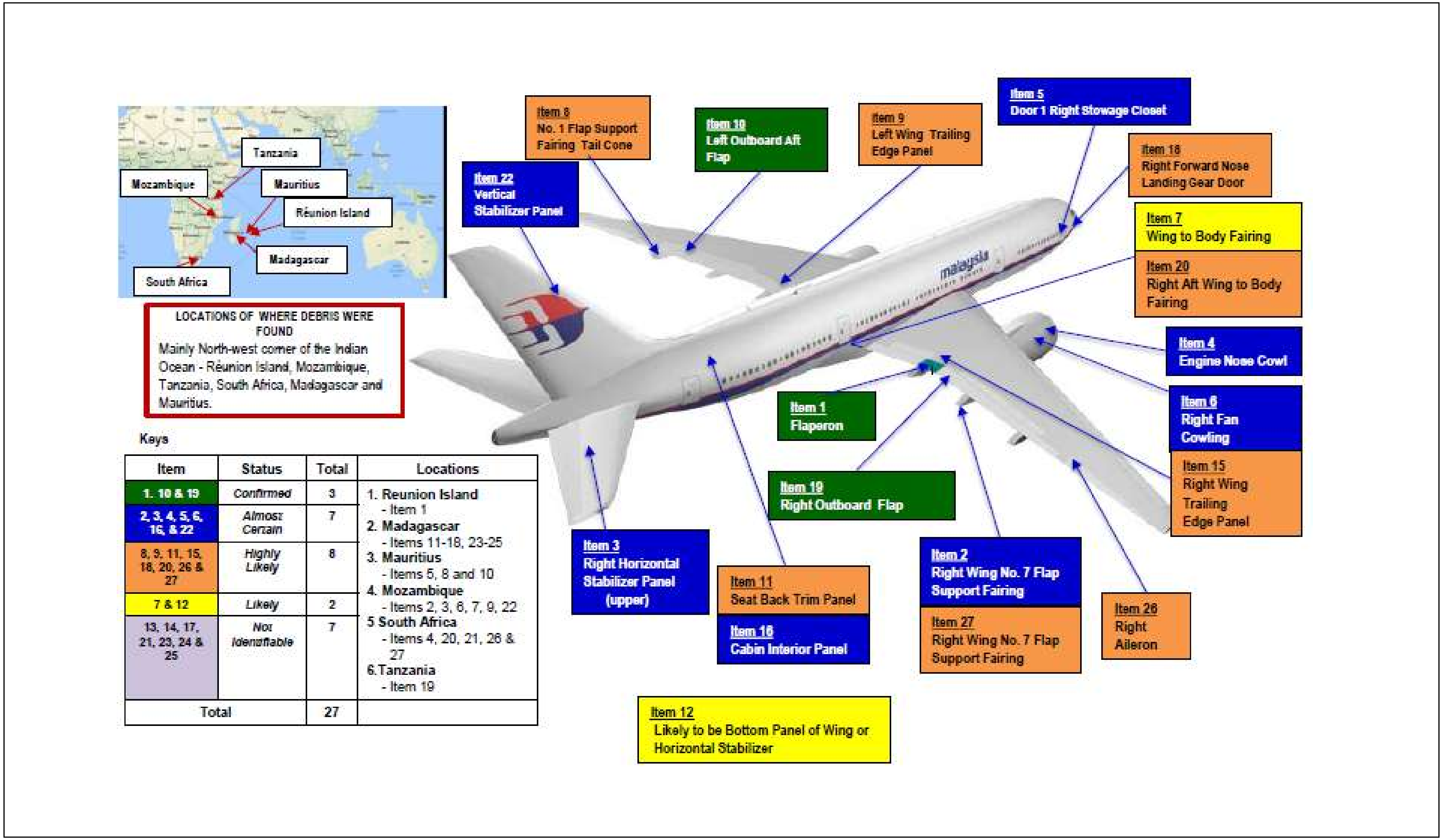
Examination, analysis and test were conducted by ATSB in Canberra, Australia and MH370 Safety Investigation Team in collaboration with STRIDE of Malaysia.

2.6.2 Location of Debris with respect to Aircraft

Figure 2.6A (below) shows the locations of the debris with respect to the aircraft.

Item 4 (part of the Engine Nose Cowl) is depicted to be from the right engine. There were no significant differentiators on the cowling segment to assist in determining whether the item of debris was from the left or right side of the aircraft, or the inboard or outboard side the cowling. Similarly, although Item 6 (part of the RH fan cowl) is depicted to be from the right engine in *Figure 2.6A,* there is a possibility that it could also be from the left engine. As for Item 7 - Wing body fairing - this too could be from either side of the aircraft.

Based on the identification of the parts and debris found, it shows that most of those parts and debris were from the right hand side of the aircraft.



Item	Status	Total	Locations
1, 10 & 19	*Confirmed*	3	1. Reunion Island - Item 1 2. Madagascar - Items 11-18, 23-25 3. Mauritius - Items 5, 8 and 10 4. Mozambique - Items 2, 3, 6, 7, 9, 22 5 South Africa - Items 4, 20, 21, 26 & 27 6. Tanzania - Item 19
2, 3, 4, 5, 6, 16, & 22	*Almost Certain*	7	
8, 9, 11, 15, 18, 20, 26 & 27	*Highly Likely*	8	
7 & 12	*Likely*	2	
13, 14, 17, 21, 23, 24 & 25	*Not Identifiable*	7	
Total		27	

Figure 2.6A - Location of Parts and Debris Found with respect to Aircraft

2.6.3 Damage Analysis of Significant Debris

Damage examination on the recovered part of the right outboard flap (Item 19), together with the damage found on the right flaperon (Item 1) indicates that the right outboard flap was most likely in the retracted position and the right flaperon was probably at, or close to, the neutral position, at the time they separated from the wing. This conclusion is based on the following findings and analysis.

There were damages to the internal seal pan components at the inboard end of the outboard flap which were possible with the auxiliary support track fully inserted into the flap. The damages were consistent with contact between the support track and flap, with the flap in the retracted position. The possibility of the damages originating from a more complex failure sequence, commencing with the flaps extended, were considered much less likely.

With the flap in the retracted position, alignment of the flap and flaperon rear spar lines, along with the close proximity of the two parts, indicated a probable relationship between two areas of damage around the rear spars of the parts. This was consistent with contact between the two parts during the aircraft breakup sequence, indicating that the flaperon was probably aligned with the flap, at or close to the neutral (faired) position. Refer to ATSB's report on the Outboard Flap Failure Analysis (*Appendix 2.6C)* for further details.

It should be noted that the DGA/TA, after examining the flaperon soon after it was found in July 2015, had concluded that the flaperon was likely to be deflected at the time of impact. This was primarily based on the damage observed on the trailing edge of the flaperon. However, this scenario was considered a hypothesis only due to lack of corroborating information, and more importantly, it was done without the benefit of the damage information available from the right outboard flap which was found much later. Additionally, the flaperon being rear of the engine, left some doubt as to its loading during the aircraft impact with the water and the phenomena at issue being highly dynamic and thus difficult to exploit. Refer to *Appendix 1.12A-2* for further details.

Two pieces of debris are *almost certain* from the cabin interior suggesting that the aircraft might have broken up. However, there is insufficient information to determine if the aircraft broke up in the air or during impact with the ocean.

Of the pieces tested so far, no traces of explosion were found.

2.6.4 Marine Life Examination

The marine organisms (barnacles) found on the flaperon were examined in detail by marine biologists, under the directive of the French Investigative judge. Below is a summary of the analysis.

The barnacles present on the flaperon belonged to the species *Lepas (Anatifa) anatifera striata*. This sub-species is strictly pelagic, always living on floating objects. It is a cosmopolitan species, widespread in worldwide oceans at tropical and temperate latitudes, in water temperatures above 18-20°C. The size of the biggest specimen indicated that the initial settlement could have occurred 15-16 months prior *to* the discovery of the flaperon at Reunion Island. The locations of the *Lepas* colony on the flaperon indicated that the flaperon was floating with its "belly face" up (the lower surface [intrados] was up, the upper surface [extrados] was immersed). Refer to *Appendix 2.6A* for details.

Temperatures during the growth of the youngest valves and the terminal fringe of the biggest adult valves (25.4 +/- 1°C) were consistent with temperatures observed off the Reunion Island. These results suggest that the barnacles ended up their developments in waters whose thermal characteristics were similar to waters close to Reunion Island, before the discovery of the flaperon.

At the beginning of their growth, the barnacles were immersed in waters with a temperature close to 28.5 +/- 1°C. Temperature distribution maps in the months preceding the discovery of the flaperon suggest that it has drifted in waters located East-North East of Reunion Island.

There are however no elements to determine precisely the duration of the growth of the valves examined, and therefore the period covered by the most developed valves. However, based on two experimental studies dealing with growth speeds of pelagic anatifas (Evans, 1958, Inatsuchi et al., 2010), the biggest valves (scutum) could have grown over a few months period. Refer to *Appendix 2.6B* for details.

SECTION 2 – ANALYSIS

2.7 ORGANISATION AND MANAGEMENT OF DEPARTMENT OF CIVIL AVIATION AND MALAYSIA AIRLINES

2.7.1 Department of Civil Aviation Malaysia

1) Introduction

In light of the disappearance of MH370 on 08 March 2014 [MYT], Malaysia as the State of Registry, State of Operator and State of Occurrence was obliged to conduct an investigation into the incident. Accordingly, the Minister of Transport had on 25 April 2014, instituted an independent international Investigation Team known as *The Malaysian ICAO Annex 13 Safety Investigation Team for MH370* with the sole objective of "prevention of future accidents or incidents and not for the purpose to apportion blame or liability." The Team, headed by an Investigator-in-Charge, comprised of nineteen Malaysians and seven international Accredited Representatives (AR) of seven safety investigation authorities from seven countries (Australia, China, France, Indonesia, Singapore, the United Kingdom, and the United States of America).

2) Department of Civil Aviation Organisation Structure

a) The Department of Civil Aviation (DCA) organisation structure at headquarters and operations resembles a flat or horizontal organisation structure which enables the officers to know what their respective responsibilities are since individual officers are assigned specific roles and functions. It enables the coordination of all activities within the DCA so that there is minimal duplication of effort or conflict and avoids overlapping of functions. As this structure creates fewer management levels, quick decisions and prompt actions can be taken without delay. Fast and clear communication is possible among these few levels of management and subordinates who are free from close and strict supervision and control.

b) This organisation structure is suitable for DCA at headquarters as the activities are rather routine and standardised. The officers at headquarters are assigned specific roles and functions enabling them to carry out their duty efficiently.

c) The DCA does not have sufficient technical personnel to effectively carry out all of its safety oversight tasks and functions due to resignations, delays in the filling of existing vacant posts, and difficulty in increasing the number of established posts in response to the growth of the industry. Uncompetitive employment conditions and the current practice of accepting technical personnel on rotational secondment from other government departments and short-term contracts from industry create difficulties in recruiting and retaining qualified and experienced technical personnel.

d) DCA is looking into the State Safety Programme (SSP) in accordance with Chapter 3, Annex 19 to the Convention on International Civil Aviation which will be applicable on 07 November 2019.

3) Air Traffic Management Sector

a) Organisation Structure

The organisation structure of the Air Traffic Manager (ATM) Sector at headquarters and operations resembles a flat or horizontal organisation structure which enables the officers to know what their responsibilities are since individual officers are assigned specific roles and functions. It enables the coordination of all activities within the ATM headquarters so that there is minimal duplication of effort or conflict and avoids overlapping of functions. As this structure creates fewer management levels, quick decisions and prompt actions can be taken without delay. Fast and clear communication is possible among these few levels of management and subordinates are free from close and strict supervision and control.

b) The ATM Sector at headquarters has a total establishment of 19 posts to manage the ATSUs in Kuala Lumpur and Kota Kinabalu FIRs and all the posts are filled and are sufficiently staffed.

c) This organisation structure is suitable for ATM headquarters as the activities are rather routine and standardised. The officers in this Sector are assigned specific roles and functions enabling them to carry out their duty efficiently. However, the personnel in ATM headquarters should closely monitor the Air Traffic Services Units (ATSUs) in the Kuala Lumpur and Kota Kinabalu

FIRs to ensure that the rules and established procedures are strictly adhered to. Periodical reminders and surprise visits to the respective ATSUs should be carried out so that the operational personnel would not lose touch with current procedures.

d) The ATM headquarters' responsibility with regard to MH370 is through the KL ATSC Director in adherence to and compliance with the rules and established procedures in the MATS Vol. 1 and Vol. 2, ICAO Annexes and Documents, Operational Letter of Agreements and Departmental Directives and Instructions, Supplementary Operations Instructions and Administration Instructions.

4) Air Traffic Inspectorate Division

a) The Air Traffic Inspectorate (ATI) Division organisation resembles a flat or horizontal organisation structure which enables the officers to know what their responsibilities are since individual officers are assigned specific roles and functions. It enables the coordination of all activities within the Division so that there is minimal duplication of effort or conflict and avoids overlapping of functions. As this structure has fewer management levels, quick decisions and prompt actions can be taken without delay. Fast and clear communication is possible among these few levels of management and subordinates are free from close and strict supervision and control. This organisation structure is suitable for the ATI Division as the activities are rather routine and standardised.

b) The ATI Division is headed by a Director and assisted by a Deputy Director. There are three units viz. Safety Oversight of ANS Providers, ATC Examination, ATC Licensing and Safety. There are three Principal Assistant Directors and three Senior Assistant Directors.

c) The ATI Division has conducted six Safety Oversight Audits on the Kuala Lumpur ATSC (KL ATSC). The last audit was conducted from 22 - 25 April 2013. The objective of the audit is to ensure conformity with ATMS prescribed standards and requirements in the provisions of ATMS by the ATM service provider.

d) The relevant ICAO Annexes, Documents and Manuals were used to identify differences between KL ATSC practices and those established by the ATM Sector, and ICAO Standard and Recommended Practices (SARPs).

e) During the on-site audit, the audit team made 6 observations, with only one having a bearing on the ongoing investigation by the Team. The observation was that the "*Direct line at Watch Supervisor console was not connected to recording facility*". During the course of the audit, there were 8 Manual of Air Traffic Services' (MATS) non-compliance reports (NCRs), 21 Annex 4's NCRs (16 Annex Chapter and 5 Annex Chapter 21), 6 Doc 9426 - ATSC Facilities NCRs and 2 ANS Regulatory NCRs. There was a total of 37 new NCRs' findings for the audit conducted in 2013. However, for the audit that was conducted in 2010, 9 out of 11 MATS' NCRs and the entire 8 Doc 9426's NCRs still remain open. There were a total of 17 NCRs still remaining open. There were 6 NCRs brought forward from 2005/2006. KL ATSC has accumulated altogether a total of 60 NCRs after the audit conducted in April A2013.

Notwithstanding the above, the Team does not find any direct link between the NCRs and the disappearance of MH370.

f) There has not been any direct link as to the functions of the ATI Division with regard to the disappearance of MH370. The ATI Division has issued ATC licenses to the ATC personnel in accordance with Personnel Licensing under Regulation 92(1) of the Malaysian Civil Aviation Regulations 1996.

5) Search and Rescue

a) Although there is no legislation specifically to address the provision of assistance to aircraft in distress, Aeronautical SAR (A-SAR) in Malaysia is provided in accordance with ICAO Annex 12 and the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual Vol. I – III (ICAO Doc 9731-AN958). It should be noted that CAR 201 stipulates the use of *'ipso facto'* to address ICAO Annexes 1 to 18, including the application of ICAO Standards and Recommended Practices (SARPs), provided that a regulation has not already been established in CAR and that a difference has not been notified to ICAO. In particular, DCA relies completely on CAR 201 for the implementation of Annexes 3, 4, 5 and 12.

b) IAMSAR Vol. IV - The National Aeronautical and Maritime Search and Rescue Manual (Malaysia), prepared under the direction of the National Search and Rescue Committee, National Security Council (NSC) and the Prime Minister's Department in March 2008, provides guidance to federal agencies concerning the implementation of the National Search and Rescue Plan. This Plan provides specific additional national standards and guidance that build upon the base line established by the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual. The IAMSAR Manual is a three-volume set published jointly by both the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO) for use by all countries. This Plan provides guidance to all federal forces, military and civilian, that support civil search and rescue (SAR) operations. It should be noted that the land (populated areas) and military SAR elements, under the portfolio of its respective ministries, are intentionally excluded from this document.

c) The IAMSAR Vol. IV is a very comprehensive national SAR manual covering areas viz.:

Part One	Aeronautical and Maritime SAR Authority and Administration;
Part Two	Aeronautical and Maritime SAR Policy
Part Three	Aeronautical and Maritime SAR Resources
Part Four	Aeronautical and Maritime SAR Communications
Part Five	Special Procedures
Part Six	Memoranda of Understanding
Plan of Operation	Part 1 - Aeronautical Part 2 - Maritime

Over the South China Sea, within the Singapore FIR, there are two distinct areas namely the South China Sea Corridor (SCSC) and the airspace delegated to KL ACC by Singapore ACC known as the "Delegated Airspace". There are special arrangements whereby the roles and responsibilities of KL

ARCC and Singapore RCC have been defined in terms of alerting service and SAR operations as follows:

i) South China Sea Corridor

The arrangement for aeronautical search and rescue service by way of the Operational Letter of Agreement between Malaysia and Singapore for the part of the South China Sea (which is within the Singapore FIR) was in force since 1984. The agreement specified the designated area, known as the South China Sea Corridor (SCSC) and stipulates that in the event of an aircraft emergency occurring within the SCSC, the KL ACC shall be responsible to take initial alerting action whilst Singapore RCC shall be responsible for subsequent coordination of all SAR efforts. Whist the responsibility for the provision of search and rescue service within the SCSC rests with the Singapore RCC, the Singapore RCC may delegate responsibility for the overall control of the SAR mission to Kuala Lumpur RCC or Kota Kinabalu RCC, whichever is deemed appropriate.

Letter of Agreement Para 3.2.2 states that*:*

When a transfer of responsibility for the overall SAR coordination is to take place, either from subsequent establishment of an aircraft's position or movement, or because an RCC other than the one initiating the action is more favourably placed to assume control of the mission by reason of better communication, proximity to the search area, more readily available facilities or any other reasons, the following procedures shall be adopted:

i) direct discussions, wherever possible, shall take place between the Search and Rescue Mission Coordinators (SMCs) concerned to determine the course of action,

ii) if it is decided that a transfer of responsibility is appropriate for the whole mission or part thereof, full details of the SAR mission shall be exchanged, the initiating RCC shall continue to retain responsibility until the accepting RCC formally assumes control for the mission.

ii) "Delegated Airspace" in Singapore FIR

The **"**Delegated Airspace" is a defined airspace over the South China Sea within the Singapore FIR that has been delegated by Singapore to Malaysia for the purpose of Air Traffic Services. SAR service is provided by Singapore.

Figure 2.7A - Kuala Lumpur - Aeronautical Rescue Coordination Centre (ARCC)

On 08 March 2014 [MYT], MH370 operated within the "Delegated Airspace". The radar position symbol dropped from the radar display at 1721:13 UTC [0121:13 MYT]. Though the KL ACC was responsible for the provision of Air Traffic Services, no alerting action was taken. At 2130 UTC [0530 MYT] the KL ATSC Duty Watch Supervisor directed the Search and Rescue Mission Coordinator (SARMC) to activate the ARCC (*Figure 2.7A* above and *Figure 2.7B* below). After the ARCC was activated, and due to a lack of details from the KL ATSC Duty Watch Supervisor, the SARMC only managed to disseminate the distress message at 2232 UTC [0632 MYT], an hour and two minutes later.

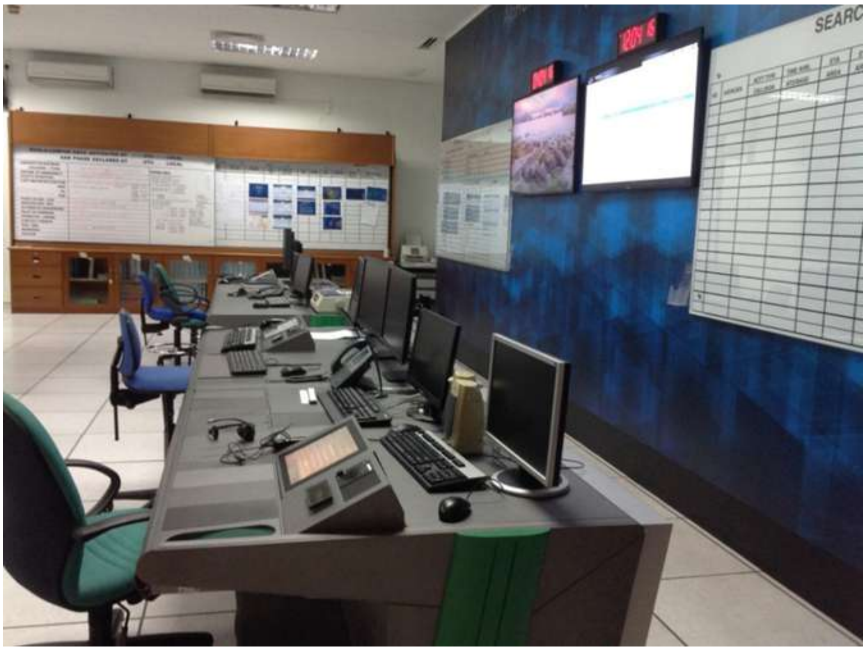


Figure 2.7B - Kuala Lumpur ARCC Work Stations

6) Kuala Lumpur Air Traffic Service Centre

a) Staffing

This analysis on the Organisation Structure of the Kuala Lumpur Air Traffic Service Centre - *Figure 2.7C* below - is based on information obtained from the Department of Civil Aviation. There are altogether 353 approved ATS posts of various grades in the KL ATSC. As of March 2015, there were 110 vacancies and 64 as of December 2014. The reason cited for the posts not being filled was *"considering the opening of klia2, DCA has managed to obtain new posts for KL ACC (Area and Approach) and KLIA on 08 May 2013. But due to the delay of klia2 opening the promotion exercise was also delayed".*

b) Findings of Safety Oversight Audit

The findings of the Final Report of the Safety Oversight Audit (Follow-up) of KL ATSC in April 2013 state that:

- *the organisational charts do not reflect the task currently*

  assigned to and being performed by the ATS staff who are also assigned secondary posts with specific duties.

- *KL ATCC had not conducted any Refresher Course for its Controllers. There is no training programme developed for ATC staff. All training is conducted on operational and opportunity basis. In addition, training records for ATC staff were not systematically maintained.*

- *No internal audit conducted however it is noted that an audit team will be established consisting of personnel who had previously attended audit course.*

The reasons cited in the audit report were inadequate staffing and inadequate resources to run the programme.

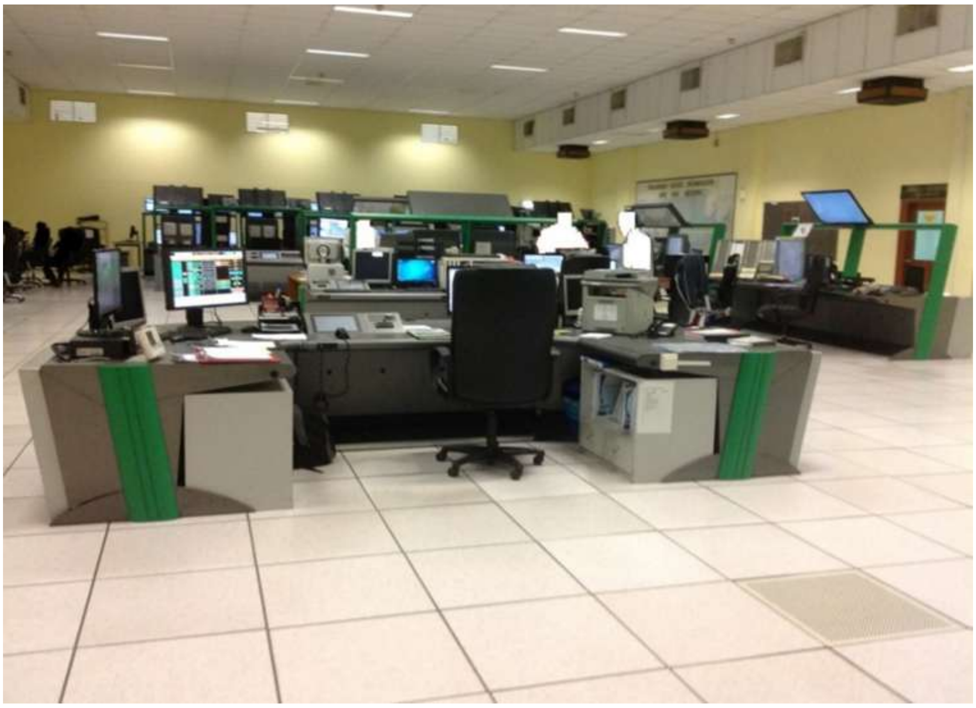


Figure 2.7C - Overview of Kuala Lumpur Air Traffic Control Centre

c) Duty Roster for March 2014

i) This analysis is based on the KL ATSC duty roster for Air Traffic Controllers for the month of March 2014. The Team acknowledges that the duty roster was prepared with the number of Controller working positions (CWPs) in the KL ATSC being filled by qualified Controllers at all CWPs.

ii) On the night of 07 March 2014, at 1500 UTC [2300 MYT] the functions of control for Sector 5 was absorbed into

Sector 3. There was no issue from this time other than that the combination of these two CWPs was carried out an hour earlier than scheduled. From 1600 UTC [0000 MYT] until 1900 UTC [0300 MYT] and 1900 UTC [0300 MYT] to 2200 UTC [0600 MYT] the Sector 3+5 radar working position was manned by radar-rated Controllers. However, it is confirmed that, from 1600 UTC [0000 MYT] till 2200 UTC [0600 MYT], the Sector 3+5 Planning Position was manned by an *OJT Controller* and an *AFD Officer* as the qualified Controllers were having their respective breaks.

Figure 2.7D - Kuala Lumpur Air Traffic Control Centre – Area Control CWPs

7) Airworthiness Sector

a) The Airworthiness Sector is not involved in the frontline operations of the aircraft. Organisational weaknesses or shortcomings of the Airworthiness Sector however may contribute to accidents due to weaknesses in the management systems and culture.

b) Areas Analysed

The following areas were analysed for latent conditions:

- Corporate goals
- Organisational Structure
- Communication
- Planning

- Control and monitoring
- Procedures
- Resources, which include:
  - Regulations
  - Safety Management

i) Corporate Goals

The Airworthiness Sector does not have specific corporate goals. It shares the Vision, Mission and values of the parent DCA. The DCA's Vision is "*to be the world's leading aviation aut*hority". Its Mission is "*to continuously enhance safety, security and efficiency for sustainable aviation industry*". These Vision and Mission do not specifically relate to the roles and functions of the Airworthiness Sector, which is to carry out "*the regulatory function in respect of airworthiness through the establishment of standards recommended practices and guidelines, and their enforcement as required by the Civil Aviation Act [CAA] 1969".* The organisational Vision and Mission are normally related to corporate goals. It is very important to instil values in each staff to achieve the corporate objectives. However, there is no direct evidence that any missing corporate goals in terms of Vision and Mission may contribute to any latent conditions which can lead to the potential failure of the system.

ii) Organisational Structure

The organisational structure of an Airworthiness Organisation is detailed in the ICAO Document 9760. The Airworthiness organisation is divided into the Airworthiness Engineering Division (AED) and Airworthiness Inspection Division (AID), as shown in *Figure 2.7E - Setup of the Airworthiness Organisation (ICAO Document 9760)*.

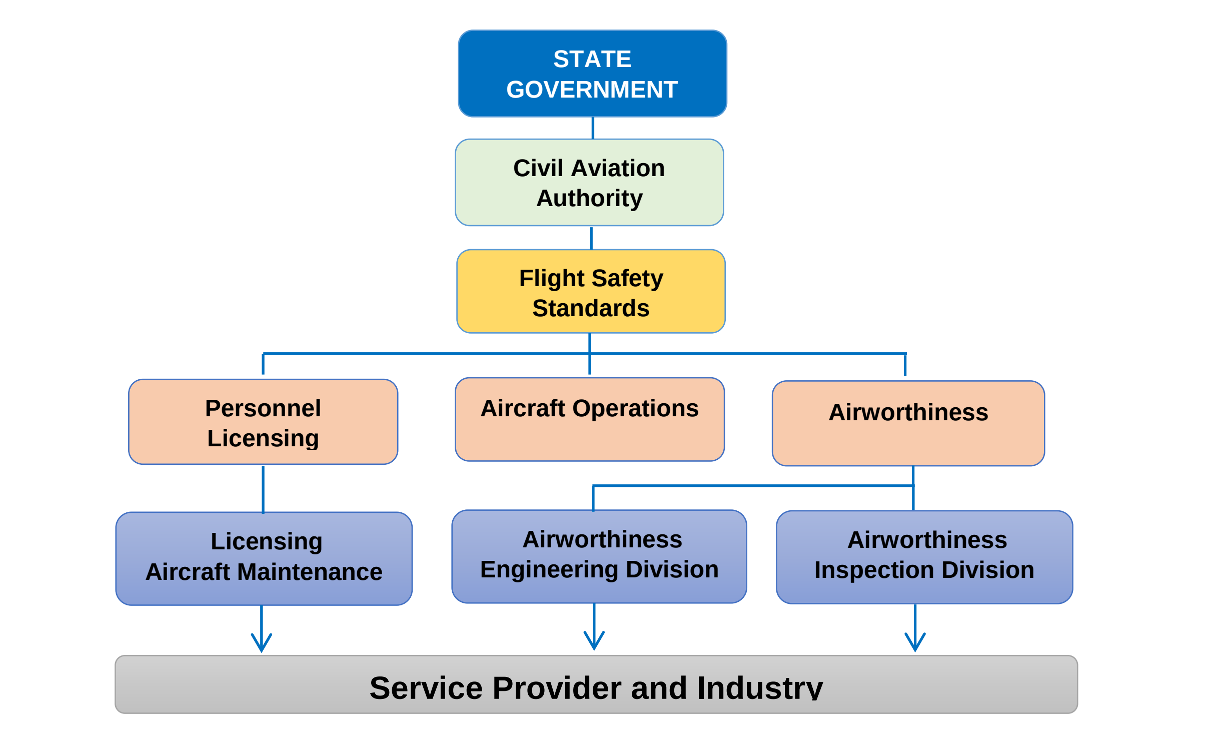


Figure 2.7E - Setup of the Airworthiness Organisation (ICAO Document 9760)

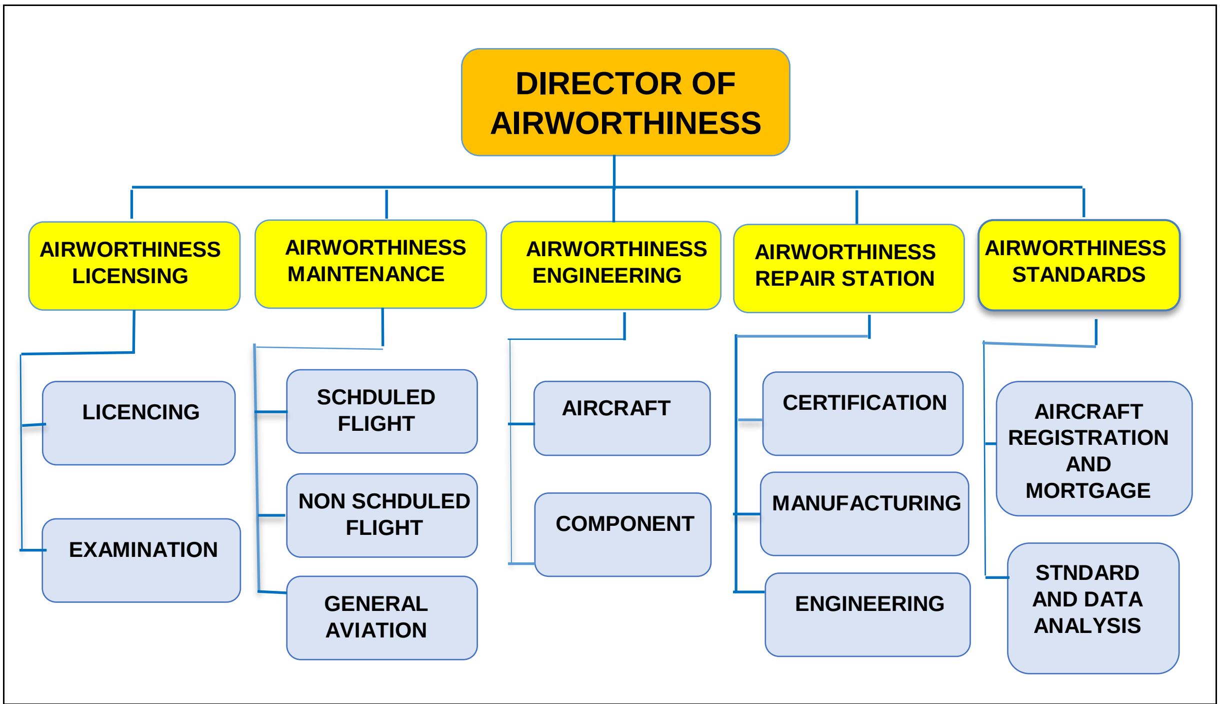


Figure 2.7F - DCA Airworthiness Sector

The DCA Airworthiness Sector is divided into 5 divisions: Airworthiness Licensing, Airworthiness Maintenance, Airworthiness Engineering, Airworthiness Repair Station, and Airworthiness Standards as in *Figure 2.7F* above.

The roles and responsibilities of each division are as follows:

- **Airworthiness Licensing** is responsible for examination of engineers, approval of training organisations, and issuance of licensing of aircraft maintenance engineers.
- **Airworthiness Maintenance** is responsible in initial issuance and renewal of Airworthiness Certificates and approval of aircraft maintenance and facilities, continuing airworthiness maintenance and investigation of incidents and defects.
- **Airworthiness Engineering** is responsible for certification of aeronautical products, issue of Airworthiness Directives (AD), approval of modification and repair, and approval of Design Organisations (DOA) and Production Organisations (POA).
- **Airworthiness Repair Station** is responsible for investigation of incidents and defects and approval of maintenance organizations/repair stations (MRO).
- **Airworthiness Standards** is responsible for registration of all civil aircraft and aircraft mortgage, to develop and update standards, requirement and procedures, analyse airworthiness data, including all occurrence reporting, service difficulties reporting, malfunction and defects.

The organisational structure of the DCA Airworthiness Sector does not clearly show the divisions of AED and AID. The licensing of aircraft maintenance is in the Airworthiness Sector. However, the analysis of the current Airworthiness Sector organisation structure indicates there are elements of AED and AID in the organisation. The AID elements are available in

Airworthiness Maintenance, and Airworthiness Repair Stations. The Airworthiness Standards cover both the AED and AID. The Airworthiness Licensing should be in the Airworthiness Sector because the DCA has a dedicated division to handle all licensing matters. Based on the organisation structure and the roles and responsibilities of each of the divisions within the Airworthiness Sector, there is no evidence of any aspects or characteristics which may lead to a latent condition.

iii) Communication

The effective external and internal communication is essential because ineffective communication and miscommunication have shown to result in unsafe condition. The Airworthiness Sector external and internal communication have been shown to be effective formally by letter and email. The internal communication is by means of meetings and discussions between the staff. The work process and activities are consistent since the Airworthiness Division Manual (ADM) is used by the airworthiness engineers and inspectors as their procedure manual when carrying out their respective tasks. Therefore, there is no evidence of any unsafe condition with respect to communication.

iv) Planning

The Airworthiness Sector carries out continuing airworthiness and surveillance oversight of aircraft maintenance activities of 8 Scheduled Operators and 21 Non-Scheduled Operators, 176 (local and international) Approved Maintenance Organisations (AMO) and 12 Approved Training Organisations (ATO). MAS was one of the major airline operators. The Airworthiness Sector also provides technical audit support in conjunction with the Flight Operations Sector and Air Transport Division to issue an Air Operating Certificate (AOC). The above activities are adequately planned and conducted, based on the schedule established for each organisation.

For the initial airworthiness certification, airworthiness inspectors and airworthiness engineers carry out new aircraft type design certification or the validation of Aircraft

Type Certificate before the aircraft is registered. The Airworthiness Sector also reviews new applications for minor or major modifications and monitoring the applicability of mandatory Airworthiness Directives issued by the State of Design.

The audit and surveillance of the organisation (i.e. MRO, ATO and AOC) and aircraft inspection for Certificate of Airworthiness (C of A) renewal are conducted on a regular basis of at least once a year. The Airworthiness Sector establishes a detailed annual audit and surveillance programme.

In the case of 9M-MRO, it was noted that the last C of A renewal for aircraft physical inspection was not carried out by the Airworthiness Inspector but was renewed based on document submission and a physical inspection report by MAS. The last aircraft physical inspection on 9M-MRO was carried out more than one year prior to the aircraft's disappearance. This is an acceptable practice by the Airworthiness Sector because the annual renewal of the Certificate of Airworthiness is normally supported by an aircraft document/physical inspection report. The mutual arrangement with the operators would indicate that the Sector has a close working relationship with the aviation industry and this arrangement serves to expedite the Certificate of Airworthiness' renewal process. Based on the above analysis, the system of planning and accomplishment are in order and there is no evidence of any latent condition which may contribute any failures.

v) Control and Monitoring

The control and monitoring mechanism requires the organisation to have key performance indicators (KPI) of its performance, hazards identification and risk management policies and programme. The aspects of hazards identification and risk management are essential for the organisation in decision making of its functions and responsibilities. The aspect of organisation key performance indicators is clearly discernible.

vi) Procedures

The Airworthiness Sector uses Airworthiness Department Manuals (ADM) as internal documented policies and procedures for the Airworthiness Engineers and Inspectors. The ADM has detailed most of the Airworthiness Sector's working procedures. However, it has not been reviewed regularly and updated in line with technological advancement. There is no specific unsafe condition, but it could be a latent condition.

vii) Resources

ICAO through Doc 9760 has recommended that inspectors and engineers possess relevant knowledge, experience and competency. The Airworthiness Sector has recruited a number of fresh engineers and inspectors to fill up the relevant posts. These new engineers/inspectors need to undergo training required under ICAO requirements.

Regulation is one aspect of the important resources required by the Airworthiness Sector. All the activities of the Sector were based on the Civil Aviation Act 1969. The Act requires compliance with the ICAO Annexes. The Act also requires the Minister of Transport to make regulations based on ICAO SARPS (Standards and Recommended Practices. The Minister of Transport formulated the Civil Aviation Regulations 1996 under the provisions of the Civil Aviation Act 1969. The analysis on the Malaysian civil aviation laws and regulations indicate that the Civil Aviation Act 1969 and CARs of 1996 may be outdated by present international regulatory standards and practices.

It is anticipated that the future introduction of the Civil Aviation Safety Requirements (CASR), Acceptable Means of Compliance (AMC) and Guidance Materials (GM) would serve to streamline the Malaysian regulatory framework, requirements and procedures, similar to the approach of the European Aviation Safety Agency (EASA) requirements. In the absence of new regulations in CAR 1996, the Airworthiness Sector has adopted and adapted other countries' laws and regulations (i.e. United States of America, European Union) and published these regulations either in notices, circulars, directives or information and issued them under section 240 (Publication of Notices) of the Civil Aviation Act 1969.

8) Flight Operations Sector

a) Corporate goals

The Flight Operations Sector (FOS) is one of the sectors of DCA Malaysia. It does not have specific corporate goals, vision or mission. It rides on the DCA Vision and Mission, which are not specific to the functions and responsibilities of the FOS. A specific vision and mission would focus the FOS inspectors on common values and practices. There is no evidence of any significant safety issue with the absence of a specific Vision and Mission for the FOS. It has no direct bearing on the disappearance of MH370.

b) Organisational structure

The FOS is divided into 5 divisions namely: Flight Crew Licensing, Air Operator Regulations, Flight Simulator, General Aviation and Flight Calibrations.

The FOS is responsible primarily for ICAO Annex 6 (Aircraft Operation) and ICAO Annex 1 (Personnel Licensing) for the flight crew. There is an operational division in the FOS - Flight Calibration Division - which operates a number of aircraft for calibration of airfields and airways. FOS is considered a mixed mode of authority-cum-operator.

c) Resources

The FOS lacks the required number of experienced inspectors (pilots). The shortage of personnel may affect the flight safety standard of the Air Operating Certificate (AOC) holders, especially with respect to the frequency of audit involving station facility inspection, RAMP Inspection for en-route and destination stop, annual inspection at every location, and base inspection for Scheduled Operations and Non-Scheduled Operations. Similarly, the shortage of flight examiners may also affect the standard of the training establishments.

The Flight Operations' Aeronautical Information Circular (AIC) No. 30/2005 November 2015 - Inspections and Investigation of Air Accidents, reiterates the statutory powers of the Minister of Transport to investigate aircraft accidents and serious incidents that occur in Malaysia regardless of nationality of aircraft registration. With respect to aircraft accidents or incidents investigation, the inspectors from the FOS may be called upon to assist the Air Accident Investigation Bureau (AAIB) under the Ministry of Transport. This function would create some constraint to the FOS in view of the shortage of experienced pilots in the Sector. This shortage is potentially a latent condition, which if not addressed, may lead to potential unsafe conditions.

Regulations is another important resource issue with the FOS working within the Civil Aviation Act 1969 and MCAR 1996. The MCAR 1996 is unable to cope with the rapid development in international aviation regulations and practices. Under the provision of section 240 of the Civil Aviation Act 1969, the AICs are published by the DCA. This practice of supplementing the CAR 1996 has been successful. However, it is still unable to cope with the up-to-date rules and regulations in Europe and North America. This condition could not have contributed to the disappearance of MH370. However, this is a latent condition which needs to be appropriately addressed.

Safety management is another important aspect in the organisation. The ICAO Annex 19 (Safety Management) has mandated the aircraft operators to develop their organisations' SMS by January 2009. To comply with the ICAO requirements, the FOS has developed the AIC No. 06/2008 which was issued under section 240 of the Civil Aviation Act 1969 for all Malaysian Air Operating Certificate (AOC) holders to establish their organisational Safety Management System (SMS). Notably, MAS had implemented the SMS into their procedures manual. The requirement for the operators to establish SMS by the FOS is adequate. However, the FOS has to establish its own safety management programme.

2.7.2 Malaysia Airlines

1) Engineering & Maintenance

Based on the factual information provided in *Section 1.17.2 para. 2)* the Engineering & Maintenance Division was well-structured appropriate to a maintenance management and maintenance organisation with key positions manned by persons approved by the Department of Civil Aviation (DCA), Malaysia. The required oversight of the maintenance activities was provided both by internal Quality auditors, as well as by the DCA Malaysia. This was further supported by audits by foreign auditors, such as from the EASA and FAA. There were no significant audit findings suggesting that the organisation was well managed. It is not unusual to have findings during audits; the purpose is to continuously improve by instituting corrective and preventive actions.

Maintenance personnel were appropriately trained and qualified in accordance with approved procedures, as documented in the Maintenance Management and Organisation Exposition (MMOE).

Although recently introduced in the year 2009, Safety Management had been embraced in the organisation and in line with the corporate system.

2) Flight Operations Management

The Flight Operations Management (FOM) office positions were sufficiently manned by qualified individuals and the working guidelines ensure their effectiveness in carrying out duties in their respective management positions. The fleet manager, being on the B777 for more than 10 years and having held the post of Type Rating Examiner (TRE), attests to his level of competency and seniority.

a) Technical Crew of Malaysia Airlines

There was no evidence of irregularities in the standards, performance and capability of pilots in Malaysia Airlines (MAS).

b) Medical Check-up

There was no evidence of irregularities in terms of medical and licensing validity of pilots in MAS.

c) Roster Schedule & Management

Data collected indicate that the pilots' roster and rest period are in compliance with MCAR FTL requirements.

There is no evidence to suggest that any of the two pilots infringed any of the required MCAR FTL limits.

d) Confidential Human Factors Incident Report System

In September 2013 to March 2014 over a period of six months, there were a total of six reports submitted, mainly on communications issues between staff.

This suggests that the CHIRPS was capturing adequate data to meet its objective.

There was no evidence to suggest that any of the two pilots were subjected to CHIRP's surveillance.

e) Flight Operations Quality Assurance

Sampling of FOQA data over a 2-year period prior to the event was studied. Capture rates were close to 100% and it is evident that the system works and justifies its role in identifying non-normal operations either deliberate or due to environment factors.

The overall rate for B777 has its average figure comparative to the industry standards.

As an example, the highest event of UA (Unstablised Approach) occurred in the month of August 2013 at a rate of 49.26 per 10,000 flight cycles. This is equivalent to 0.49% for the month.

The highest FOQA trigger was the long flare event which occurred in the month of May 2012 at 243.6 per 10,000 flight cycles. This is equivalent to 2.3% for the month.

Based on these findings, enhanced training on the proper corrective measures was introduced during recurrent simulator checks.

f) Line Operations Safety Audit

The findings were very relevant, and recommendations were implemented via Safety Change Process (SCP). MAS on the average had less findings compared with the other 5 airlines in the Line Operations Safety Audit (LOSA) archive. Safety Change Process was carried out to mitigate the findings. LOSA findings also revealed low prevalence in terms of overall mismanagement rate (unsafe operations) in the B777 fleet as reported in MAS LOSA Report 2011. LOSA was conducted by taking a random sampling on all fleets including the B777. MAS had met the average safety standards of most international airlines.

g) Crew Resources Management

The Team's analysis reveals that the CRM programme had been implemented and had produced positive results over the years. These awareness and regular recurrent training programmes had inculcated good interpersonal relationships between flight crew members and had contributed significantly to the overall safety of the flight operations.

Both the technical and cabin crew were in compliance with CRM requirements.

h) Safety and Emergency Procedures

Findings have indicated that both the technical and cabin crew were in compliance with SEP validity. The training syllabus had met all the regulatory requirements.

i) Flight Deck Security Procedures

At the time of flight MH370, there were no requirements for an additional crew member in the cockpit in the event when one of two pilots were to leave the cockpit. However, in response to flight MH370, MAS has, since introduced this requirement into its safety procedures effective 27 March 2014, a procedure subsequently introduced by other airlines following the GermanWings Flight 9525 accident on 24 March 2015.

j) MAS B777 Training and Standards

The fleet carried sufficient numbers of Type Rating Examiners (TRE) and Type Rating Instructors (TRI) to fulfil the licensing requirements. TRE and TRI were Captains from within the airline, appointed with approval from the Licensing Section of the DCA. They were also tasked with monitoring the overall standards to be maintained by the fleet. This responsibility was under the jurisdiction of the Training and Standards Department, which was headed by a Chief Pilot.

k) Multi-crew Operation MH370

Flight MH370 was operated on a normal 2-man crew operation with one PIC and one FO. A third pilot was not required as a safety pilot as the trainee's performance was reported to be above average and deemed safe by the previous Training Captain.

The duration of the scheduled flight with FDP (Flight Duty Period) of less than 8 hours also justified the 2-man crew operations.

l) Operation Control Centre

During the day of the disappearance of MH370, it was established that the FFS was programmed to receive a download from the aircraft at 30 minute intervals. The last download was transmitted at 1707:29 UTC [0107:29 MYT]. As a result, the track and position shown on the monitor after this time was only the predicted track and position.

Facts gathered during interviews with despatchers on duty during the incident suggested that with the exception of hijack and bomb hoax, there were no quick references to guide the frontline operations staff to react to emergency situations such as a lost aircraft and a crash.

The FFS was observed to be in accordance ICAO Annex 6 Part 1 Chapter 4, AIC 10/2002 dated 25 July 2002 and FOSI[38] Handbook, Vol 3, Chapter 4, para 6. Personal interviews with individual despatchers suggested increased workload which could

[38] This order is referred to as a handbook and directs the activities of Flight Operations Surveillance Inspectors (FOSI) who are responsible for the certification, technical administration, and surveillance of scheduled air carriers and certain other air operators who conduct their operations in accordance with the Malaysian Civil Aviation Regulations 1996, made under the Civil Aviation Act 1969.

have affected the quality of work. There is evidence that the Supervisor/Despatcher-in-charge oversaw an average of 30 flights on that particular night shift, including monitoring seven to eight different flights at one time on the Orient Sector. This suggests the existence of an element of overworked condition.

The Team's investigation into the basic capability of the FFS suggested that there are bound to be discrepancies between the actual aircraft position compared to the projected flight path in the FFS once an automatic update stops. This could explain the state of confusion and uncertainties among all parties involved during the incident. These discrepancies suggest two hypotheses:

- Data downlink failure from the ACARS communication.
- Intentional or unintentional deactivation of ACARS Communications.

The position update on the FFS was programmed at 30 minute intervals on the B777. This interval is the same as the B747-400 but comparatively longer than other aircraft (A380: 10 mins; A330: 10 mins; B737-800: 10 mins).

The displayed aircraft position was erroneous right from the point where the ACARS communication was lost.

m) Fuel Policy

There is no evidence to suggest that the PIC had ordered or carried any extra amount of fuel beyond the minimum amount recommended by the Computerized Flight Plan. This was in compliance with the Company's fuel policy.

No irregularities were found in the fuel computation and fuel flight plan.

n) Flight Plan Routing

There is no evidence in terms of out-of-normal flight planning on the KUL/PEK sector nor any deliberate rerouting to suggest that the PIC might have the intention to carry extra fuel. Nonetheless, it is a captain's authority to carry additional fuel if he thinks it is justified and to override the despatcher's decision.

No irregularities were found in the aircraft flight plan.

3) In-flight Services

a) Cabin Crew Training

The cabin crew of MH370 were provided with proper training on Safety and First Aid. They were also trained to handle:

i) Safety and emergency evacuation.
ii) Disruptive/difficult passengers.
iii) Medical emergency (provision of First Aid).

Crew Resource Management (CRM) is part of the mandatory programme in cabin crew training. It is on record that the IFS did his CRM a day before the departure of the MH370 flight (the most current in the CRM recorded was from the IFS where it was noted that he did his CRM a day before the departure of the MH370 flight).

All the cabin crew of MH370 were trained with Safety procedures and in compliance with regulatory and Company's requirements.

b) Crew Performance Appraiser

The Crew Performance Appraiser (CPA) system was an established process in the organisation to monitor crew performance and standards including safety knowledge.

The organisation had a clear system on the CPA monitoring process that, if a crew member had failed to carry out the required CPA, the crew member was reminded by the system or the Ward Leader[39] to follow up on the crew member apart from alerting the Crew-in-charge to ensure that the crew member would have to fulfil the requirement within the stipulated cycle in a year.

There is no evidence to indicate that the disappearance of MH370 was attributed to poor crew performance.

c) Medical Record

The cabin crew of MH370 had undergone a medical check-up as a requirement during the initial crew training. However, medical check-up was never made compulsory as a yearly pre-requisite. There is no evidence to suggest that the disappearance of MH370 was attributed to medical conditions of the cabin crew.

[39] Ward Leader – An executive assigned to monitor the performance, discipline and welfare of cabin crew.

d) In-flight Operation

To efficiently carry out the duties that include in-flight customer services including serving passenger meals, MAS had established the need to carry 11 cabin crew members. MH370 however departed with only 10 cabin crew members, 1 less than the normal compliment. It is an established fact that, based on regulation, the minimum crew required are 8, consistent with the number of doors/Emergency Exits available on the B777. It is unlikely that any of the crew were subjected to exhaustion before or while on duty on the ill-fated flight.

MAS was then facing acute shortage of cabin crew resulting in flights departing with under-strength crew complements from the numbers normally required on many of their aircraft operations in the past year.

The flight departed within the legal minimum crew requirement as per the local Civil Aviation Requirement. Shortage of manpower can lead to personnel fatigue even though it is within the legal requirement and acceptable operations.

Nevertheless, there is no evidence to indicate that exposure to stress and overwork had contributed to the disappearance of MH370.

e) Flight Time Limitation

The Malaysia Airlines Employee Union (MASEU) was the recognised Union Organisation endorsed by MAS to represent the cabin crew. The Flight Time Limitation (FTL) and the working conditions were governed by the Collective Agreement (CA) signed between the Union and MAS in accordance with the Civil Aviation Regulations 1996, whichever was the more limiting.

Another Union - the National Union Flight Attendants Malaysia (NUFAM) - was later formed and sought recognition to represent the crew's Collective Agreement (CA). A secret ballot was held in July 2013 and NUFAM won the election with a majority of 60% indicating the cabin crew's preference. However, MAS Management did not recognise the Union. This stalemate had delayed the renewal of the Collective Agreement which expired in August 2013.

There was no infringement of the FTL. The cabin crew were in compliance with the requirements of the Civil Aviation Regulations 1996.

There is no evidence to indicate that the disappearance of MH370 was attributed to insufficient rest or exceeding permitted working hours.

FTL is not a contributing factor to the disappearance of MH370. However, the crew's working conditions and FTL were subject to each organisation's MOU with the approval of the DCA as a regulator. The crew were in compliance with the requirements of the Civil Aviation Regulations 1996.

SECTION 2 – ANALYSIS

2.8 AIRCRAFT CARGO CONSIGNMENT

2.8.1 Cargo on Board MH370

1) The gross weight of the cargo carried on board MH370 was 10806 kg (cargo plus packing materials, pallets and ULDs).

2) The nett and gross weight of the cargo are as depicted in *Table 2.8A* (below).

<table>
<tr><th rowspan="2">CARGO ITEMS</th><th colspan="2">WEIGHT (in kg)</th></tr>
<tr><th>NETT</th><th>GROSS</th></tr>
<tr><td>Scholastic Assorted Books</td><td>2,250</td><td>2,320</td></tr>
<tr><td>Lithium Ion Batteries</td><td>221</td><td rowspan="2">2,650</td></tr>
<tr><td>Walkie Talkie and Radio Accessories and Chargers</td><td>2,232</td></tr>
<tr><td>Electrical Parts (Capacitors)</td><td>26*</td><td rowspan="3">(410 + 394) 804</td></tr>
<tr><td>Vehicle Electronic Chips</td><td>6*</td></tr>
<tr><td>Electronic Measurements</td><td>646*</td></tr>
<tr><td>Fresh Mangosteens</td><td>4,566</td><td>4,926</td></tr>
<tr><td>Courier Materials - Documents</td><td>6</td><td>6</td></tr>
<tr><td>Total</td><td>9,953</td><td>10,806</td></tr>
</table>

Table 2.8A - Cargo List

* *shared cargo position*

3) There were 2 items of concern viz. Lithium Ion (Li-ion) batteries and mangosteen fruit. The batteries were speculated to be a fire hazard and the mangosteens were also speculated to be out of season at that time of the year.

4) A total of 36 shipments of Li-ion batteries and accessories and mangosteens were flown together to China on previous flights (*Appendix 1.18J - Airways Bills from January to May 2014)***.** There were no reports of any incidents concerning these cargo shipments.

5) During the Team's visit to NNR Logistics, Tianjin, China the forwarding agent for Motorola confirmed that they had reserved cargo space on all MH370 departures out of Kuala Lumpur to Peking for the carriage of Motorola products. NNR Logistics had also highlighted that, in compliance with Motorola's stringent Standard Operating Procedures

(SOP), any damaged boxes would be rejected during physical inspection and loading.

2.8.2 Li-ion Batteries on Board MH370

1) Of the total consignment of 2,453 kg from Motorola Solutions Penang, only 221 kg were Li-ion batteries in compliance with Section II of Packing Instruction 965; the rest comprised Radio Accessories and Chargers.

2) Testing of the Li-ion batteries was carried out by the Company's Research & Development Department in the United States of America as per Certificate of Compliance, Certificate No. 12GEM0185 with Issue Date: 12-09-2012 for PMNN4081BRC; and Certificate No. 13GEM0300 with Issue Date: 2013.10.25 for PMNN4073AR. *Appendix 2.8A - Certificates of Compliance (Rev 14 and 15).*

3) The shipments from Motorola Solutions, transported to the Penang MASkargo Complex by NNR were physically (external visual inspection but did not involve the breaking down of the cargo) inspected by the MASkargo handlers in Penang but not screened by MAS security personnel by means of an x-ray screening machine. At that time there were no available x-ray machines on the landside large enough to screen the consignments. In June 2014, Penang MASkargo had acquired three machines capable of screening large consignments which were fully operational in July 2014.

4) The security procedures are in accordance with Amendment 13 of ICAO Annex 17 which came into force on 15 July 2013 where all cargo are required to undergo physical security screening as per DCA Director General Directive No. 1A/2013 (AVSEC) Physical Security Screening-Enhanced. There is also a Director General Directive No. 2/2013 (AVSEC) on Air Cargo Transhipment in Malaysia effective 15 July 2013 which allows this procedure (*Appendix 2.8B - Director General Directive No. 1A/2013 and Appendix 2.8C - Director General Directives No. 2/2013*).

   After the physical inspection by MASkargo personnel, the loaded consignments went through Customs inspection and clearance. The truck was then sealed by Customs and MAS Security before being allowed to leave the Penang cargo complex enroute to KLIA under escort. The truck made a routine resting stop at Rest and Recreation

(R n R) Centre, Tapah, Perak on the North-South Highway. The two drivers interviewed revealed that the truck was never left unguarded by them or the security escort. The shipment arrived at KLIA Cargo Complex on the evening of 07 March 2014, before the seals were broken and the cargo loaded onto MH370 without further screening.

The security procedures for the cargo from Motorola Solutions to KLIA, Sepang were reviewed and found in accordance to the standard operating procedures.

2.8.3 Mangosteen Fruits on Board MH370

The Team confirmed that MH370 was carrying mangosteens to China. Contrary to speculations that the fruits were out of season, it was found to be in season in Muar, Johore and neighbouring countries. At the time of writing of this report the fruits are still being exported by the same company to Beijing, China.

2.8.4 Dangerous Goods

1) The Li-ion batteries carried on board MH370 were not listed as dangerous goods (DG) and as such they were in compliance with Section II of Packing Instruction 965. Hence, there was no requirement for the pilots to be informed. However, the mangosteens were declared in the Special Load Notification to Captain (Doc. DVC-17957 1529 07Mar14 (*Appendix 2.8D*) and the Letter and Directive by the Director General (*Appendices 2.8B and 2.8C*) as it is classified as a perishable item.

2) Both pilots were trained on DG procedures and were periodically updated (once every two years) in their Safety and Emergency Procedures (SEP) training programme. *Table 2.8B (*below) shows the training programme.

Crew	SEP Expiry Date	CRM Date Attended	DG Cat 10
Pilot	17 August 2014	07 September 2011	24 February 2014

Table 2.8B - Table for Technical Crew SEP/CRM/DG CAT

2.8.5 Laboratory Tests Conducted

After the disappearance of MH370, laboratory tests on Li-ion batteries and mangosteens were conducted by STRIDE, Malaysia to determine their individual and/or combined reactions under certain conditions. Refer to *Appendix 2.8E Laboratory test on Li-ion batteries and mangosteens.* The test results are as follows:

1) Li-ion Batteries

a) High Temperature Tests

i) Point of bulging was at 175° C;

ii) Point of fuming was at 187° C;

iii) Point of eruption was at 207° C;

iv) At peak, release of carbon monoxide (CO) was at 176.5 ppm;

v) At peak, release of carbon dioxide (CO2) was at 471 ppm.

b) Functional and Voltage Capacity Tests

i) All the batteries tested were functioning normally.

ii) Average capacity of 60% or about 7.3V from full capacity of 11V.

c) Drop Tests

The tests were carried out with batteries (window white box in brown box *(Figure 2.8A*, [below]) dropped at a height of 120.92 cm (48 inches) on to a wooden platform. It was found that the batteries had no observable physical damage and functioned normally.

i) Short Circuit Tests

- The batteries produced sparks when electrodes (Positive and Negative) touched directly.
- The batteries did not produce sparks when the electrodes were touched with cardboard soaked in water from sponge or mangosteen extract.

ii) Built-in Voltage and Current Protection Circuit Tests

- The batteries also have a built-in voltage and current protection circuit. "…*Cell protection features consist of internally trimmed charge and discharge voltage limits,* *discharge limit with a delayed shutdown and an ultra-low current sleep mode state when the cell is discharged.*"

Figure 2.8A - 2 Batteries in window white box and placed in a brown box

2) Mangosteen Fruits

a) pH Value Tests

Water from the sponge used to keep the fruit fresh was tested and found to have a pH value of 6 and the mangosteen juice had a pH value of 3.

b) Conductivity Tests

- When current was passed through distilled water, the current flow indicator did not light up (distilled water was not conductive);
- When current was passed through mangosteen extracts, the current flow indicator lit up (mangosteen extract was conductive);
- When current was passed through water from the sponge, the current flow indicator lit up (water from the sponge was conductive).

2.8.6 Effects of Close Proximity of Li-ion Batteries and Mangosteens in Cargo Consignment

1) Location of Cargo

In one of the cargo compartments on MH370 the Motorola Solutions batteries and mangosteens were placed next to each other (No. 1 and 'A'). Even though they were placed next to each other in the aircraft (*Figure 2.8B* [below]), the mangosteens were packed in plastic crates and placed in Unit Load Device (ULD) containers. The consignment was also wrapped in a plastic sheet to make it water-proof to a certain extent.

Figure 2.8B - Sample ULD and Batteries placed next to each other

2) Results of Tests

There were concerns that the mangosteen extracts could have got into contact with the batteries and produced hazardous fumes or in a worst case scenario caused a short circuit and/or fire. These tests were carried out and the results are as follows:

i) This was highly improbable on board MH370 with a comparatively short flight duration and under controlled conditions.

ii) After carrying out the tests, STRIDE was convinced that the two items tested could not be the cause in the disappearance of MH370. The Team concurs with STRIDE's findings.

SECTION 3 – FINDINGS AND CONCLUSION

3.1 Findings

3.1.1 Diversion from Filed Flight Plan Route

1) Flight MH370 had diverted from the Filed Flight Plan route.

2) There is no evidence to indicate that MH370 was evading radar.

3) Only the transponder signal of MH370 disappeared from the ATC Controller radar display whilst the (radar) position symbols from other aircraft were still available.

4) The reason for the transponder information disappearing from the aircraft could not be established.

5) It could not be established whether the aircraft was flown by anyone other than the pilots.

6) The reconstruction flight conducted on the B777 flight simulator had established that the turn back was likely made while the aircraft was under manual control and not the autopilot. However, it could not be established that the other two turns over the south of Penang and the north of MEKAR were made under manual control or autopilot.

7) The aircraft primary radar target was designated as ‘friendly’ by the Royal Malaysian Air Force as it did not pose any threat to national airspace security, integrity and sovereignty.

8) There were uncertainties on the position of MH370 by both Kuala Lumpur ACC and Ho Chi Minh ACC.

3.1.2 Air Traffic Services Operations

1) Kuala Lumpur Air Traffic Services

a) KL ATSC operation was normal with no significant observation until 1720 UTC [0120 MYT].

b) KL ACC controllers transferred MH370 to Ho Chi Minh ACC at 1719:26 UTC, 3 minutes before the original estimate time of the transfer of the control point.

c) HCM ACC did not notify KL ACC when two-way communication was not established with MH370 within five minutes of the estimated time for the transfer of control point.

d) KL ACC controllers relied solely on position information of the aircraft provided by MAS Flight Operations Despatch Centre rather than checking up with other ATC authorities.

e) The Air Traffic controllers did not initiate, in a timely manner, the three standard emergency phases in accordance with the standard operating procedures.

f) There is no record to suggest that the KL ACC controllers took any action to alert the RMAF Joint Air Traffic Control Centre (JATCC).

g) There is no evidence to suggest that the Air Traffic controllers at KL ACC had kept continuous watch on the radar display.

h) KL ACC controllers did not comply fully with established ATC procedures.

2) Ho Chi Minh Air Traffic Services

a) There were uncertainties on the position of MH370 by both KL ACC and HCM ACC.

b) The command of the English language in the coordination process between KL ACC and HCM ACC needs improvement.

c) HCM ACC did not notify KL ACC when two-way communication was not established with MH370 within five (5) minutes of the estimated time for the transfer of control point.

3.1.3 Flight Crew Profile

1) General and Specific Human Factors Issues

a) There is no evidence to suggest any recent behavioural changes for the PIC, FO and cabin crew.

b) There is no evidence to suggest a pattern of regular over-the-counter medication purchase by the PIC. However, the possibility that such medication may have been purchased by cash cannot be excluded.

2) Human Factor Aspects of Air Traffic Control Recordings

a) The voice transmission for the first 3 sets of recordings were those of the FO before take-off and the 4th and 5th sets were from the PIC after take-off.

b) The last radio transmission "*Good Night Malaysian Three Seven Zero"* was spoken by the PIC. However, he did not readback the assigned frequency, which was inconsistent with radio-telephony procedures.

c) The radio-telephony communications conducted by the PIC and the FO with the Air Traffic Controllers revealed no evidence of anxiety or stress detected in the conversations.

3.1.4 Airworthiness & Maintenance and Aircraft Systems

1) The maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures, except for the instance of the Solid-state Flight Data Recorder Underwater Locating Beacon (SSFDR ULB) battery which had expired in December 2012.

2) The aircraft had a valid Certificate of Airworthiness.

3) The aircraft was airworthy when dispatched for the flight.

4) The mass and the centre of gravity of the aircraft were within the prescribed limits.

5) Although it cannot be conclusively ruled out that an aircraft or system malfunction was a cause, based on the limited evidence available, it is more likely that the loss of communication (VHF and HF communications, ACARS, SATCOM and Transponder) prior to the diversion is due to the systems being manually turned off or power interrupted to them or additionally in the case of VHF and HF, not used, whether with intent or otherwise.

6) The recorded changes in the aircraft flight path following waypoint IGARI, heading back across Peninsular Malaysia, turning south of Penang to the north-west and a subsequent turn towards the Southern Indian Ocean are difficult to attribute to any specific aircraft system failures. It is more likely that such manoeuvres are due to the systems being manipulated.

7) The SATCOM data indicated that the aircraft was airborne for more than 7 hours suggesting that the autopilot was probably functioning, at least in the basic modes, for the aircraft to be flown for such a long duration. This in turn suggests that the air and inertial data were probably available to the autopilot system and/or the crew.

8) The inter-dependency of operation of the various aircraft systems suggests that significant parts of the aircraft electrical power system were likely to be functioning throughout the flight.

9) Without the benefit of the examination of the aircraft wreckage and recorded flight data information, the investigation is unable to determine any plausible aircraft or systems failure mode that would lead to the observed systems deactivation, diversion from the filed flight plan route and the subsequent flight path taken by the aircraft.

10) No Emergency Locator Transmitter (ELT) signal from the aircraft was reported by the responsible Search and Rescue agencies or any other aircraft.

3.1.5 Satellite Communications

1) Throughout the flight of MH370 the aircraft communicated through the Inmarsat Indian Ocean Region (IOR) I-3 Satellite and the Ground Earth Station (GES) in Perth, Australia.

2) At 1707 UTC (07 March 2014), the SATCOM system was used to send a standard ACARS report, normally sent at every 30 minutes. The ACARS reports expected at 1737 UTC and subsequently were not received. The next SATCOM communication was a log-on request from the aircraft at 1825 UTC, followed by two IFE Data-3 channel setups. From that point until 0011 UTC (08 March 2014), SATCOM transmissions indicate that the link was available, although not used for any voice, ACARS or other data services apart from two unanswered ground-to-air telephone calls. At 0019 UTC, the Airborne Earth Station (AES) initiated another log-on request. This was the last SATCOM transmission received from the AES.

3) Data from the last seven ‘handshakes’ were used to help establish the most probable location of the aircraft. Both the initial log-on request and the hourly ping have been termed as a ‘handshake'. Two unanswered ground-to-air telephone calls at 1839 and 2313 UTC (07 March 2014) had the effect of resetting the activity log and hence increased the period between the ground initiated ‘handshakes’.

4) The two Log-Ons, at 1825 UTC (07 March 2014) and 0019 UTC (08 March 2014), were initiated by the aircraft most likely due to power interruptions to the SATCOM avionics.

5) The power interruption leading up to 1825 UTC was probably due to power bus cycling, the reason for it being unknown. The power interruption leading up to 0019 UTC was probably due to low fuel at this time resulting in the loss of both engines and their respective generators. There was probably enough fuel for the APU to start up and run long enough for its generator to power the SATCOM avionics (SATCOM AES) to initiate a log-on request.

3.1.6 Wreckage and Impact Information

1) The main wreckage belonging to MH370 has so far not been found. However, a number of debris were found washed ashore near and onto the south eastern coast of Africa.

2) Only the parts washed ashore on La Reunion Island (the right flaperon), Tanzania (part of the right outboard flap) and Mauritius (a section of the left outboard flap) were confirmed to be from MH370. Although the name plate was missing, which could have provided immediate traceability to the accident aircraft, the flaperon was confirmed to be from the aircraft 9M-MRO, by tracing the identification numbers of the internal parts of the flaperon to their manufacturing records at EADS, CASA, Spain. Similarly, the Italian part manufacturer build records for the numbers located on the right outboard flap part confirmed that all of the numbers related to the same serial number outboard flap shipped to Boeing for aircraft 9M-MRO. As for the section of the left outboard flap, a part identifier on it matched the flap manufacturer supplied records which indicated a unique work order number and that the referred part was incorporated into the outboard flap shipset line 404 which corresponded to the Boeing 777 aircraft line number 404, registered 9M-MRO and operating as MH370.

3) To date, 27 items of debris were considered significant for examination. Of these, other than the flaperon, a part of the right outboard flap and a section of the left outboard flap, 7 items were also considered *almost certain* to be from MH370.

4) Damage examination on the recovered part of the right outboard flap, together with the damage found on the right flaperon indicates that the right outboard flap was most likely in the retracted position and the right flaperon was probably at, or close to, the neutral position, at the time they separated from the wing.

5) Recovery of the cabin interior debris suggests that the aircraft was likely to have broken up. However, there is insufficient information to determine if the aircraft broke up in the air or during impact with the ocean.

3.1.7 Organisational and Management Information

1) Department of Civil Aviation

a) The regulatory system in Malaysia includes Regulation 201 of MCAR 1996 that applies ICAO Annex 1 to 18 "*ipso facto*". However, the resulting regulatory framework under this *"ipso facto"* regulation in Malaysia does not enable an effective implementation of all ICAO Annex provisions. With the introduction of Annex 19 dedicated to a Safety Management System, applicability date 14 November 2013, the *"ipso facto"* provision does not include Annex 19.

b) DCA is looking into the establishment of a State Safety Programme (SSP) for the management of safety in the State that will be applicable on 07 November 2019.

c) The organisation structure is suitable for DCA at headquarters as the activities are routine and standardised.

d) On Search and Rescue, there is a comprehensive arrangement in dealing with an aircraft emergency between Malaysia and neighbouring States which requires the provision of A-SAR services on a 24-hours daily basis fulfilling the international obligations.

e) Kuala Lumpur Air Traffic Control Centre

i) DCA has a policy of retaining retiring ATCOs on a contract basis to ensure that the number of qualified and rated Controllers remains status quo and that there is a transfer of technology, experience and expertise.

ii) Although no internal audit had been conducted, it is noted that an audit team will be established consisting of personnel who had previously attended audit courses.

iii) All ATC training courses were conducted on operational and opportunity basis.

2) Malaysia Airlines

a) Engineering & Maintenance

i) The Engineering & Maintenance Division was a well-structured maintenance management and maintenance organisation with key positions manned by persons approved by the Department of Civil Aviation (DCA), Malaysia.

ii) Proper oversight was provided both by internal and external audits. There were no significant audit findings.

iii) Maintenance personnel were appropriately trained and qualified in accordance with approved procedures.

b) Flight Operations

i) There is no evidence of irregularities of both the pilots in terms of their capability, performance and standard to assume command of a B777 and as First Officer respectively prior to the disappearance of MH370.

ii) There is no evidence of irregularities in terms of Medical & Licencing Validity of both the pilots prior to the disappearance of MH370.

iii) There is no evidence of irregularities in Roster Schedule and Management.

iv) The findings of LOSA were very relevant and recommendations were implemented via a Safety Change Process (SCP). MAS had met the average safety standards of most international airlines.

v) Both the Technical Crew & Cabin Crew were in compliance with CRM requirements.

vi) During the period of the incident there was no enhanced special security alert status declared by MAS.

vii) there were no training records available for the FO from the beginning of his simulator training and initial operating experience (IOE) to his present fleet where he was still under training. All the training reports were with him in his personal training file on board the flight.

viii) Based on past training records, there is no evidence that both the pilots' performance was below the Company's standard since their employment with MAS.

ix) The duration of the scheduled flight with Flight Duty Period (FDP) of less than 8 hours and the training policy justify the 2-man crew operations.

x) An element of overworked condition in the MAS Operation Control Centre existed.

xi) The displayed aircraft position on the Flight-Following System was erroneous right from the point where ACARS communication was lost.

xii) No irregularities were found in the fuel computation and fuel flight plan.

xiii) No irregularities were found in the aircraft flight plan.

xiv) The cabin crew were subjected to thorough medical check-ups as a requirement during the initial recruitment before employment and neither the Company nor the Regulatory body made it a requirement after being employed. However, there was no strict monitoring on the crew's health and mental health in the Standard Operating Procedures (SOP).

xv) The flight departed within the legal minimum cabin crew requirement.

3.1.8 Aircraft Cargo Consignment (Lithium Ion Batteries and Mangosteen Fruits)

1) The two cargo items in question which were carried on MH370 had also been transported via scheduled flights on MAS before and after the event.

2) The Lithium ion batteries (listed as non-dangerous goods), were packed and land-transported out from the production factory to KLIA Sepang in accordance with existing and approved regulations and procedures.

3) Extensive tests conducted on the mangosteens packed with water-soaked foam and juice extracts of mangosteens in contact with Lithium ion batteries revealed that this could only be hazardous if exposed to a certain extreme condition and over a long period of time. This was highly improbable on board MH370 which had a comparatively shorter duration of flight time and was under controlled conditions.

4) There was no cargo classified as dangerous goods on board MH370. The batteries on board were not classified as Dangerous Goods because the packing adhered to the guidelines as stipulated in the Lithium Battery Guidance Document.

SECTION 3.2 – Conclusion

On 08 March 2014, MH370, a scheduled passenger flight from Kuala Lumpur to Beijing, operated by MAS went missing soon after a routine handover from the Malaysian ATC to Viet Nam ATC. Communications with the aircraft were lost after it passed waypoint IGARI, less than 40 minutes after take-off. The aircraft operating the flight was a Boeing 777-200ER, registered 9M-MRO. On board the aircraft were 12 crew and 227 passengers (239 persons in total).

Evidence shows that Flight MH370 diverted from the Filed Flight Plan route. The aircraft's transponder signal ceased for reasons that could not be established and was then no longer visible on the ATC radar display. The changes in the aircraft flight path after the aircraft passed waypoint IGARI were captured by both civilian and military radars. These changes, evidently seen as turning slightly to the right first and then to the left and flying across the Peninsular Malaysia, followed by a right turn south of Penang Island to the north-west and a subsequent (unrecorded) turn towards the Southern Indian Ocean, are difficult to attribute to anomalous system issues alone. It could not be established whether the aircraft was flown by anyone other than the pilots. Later flight simulator trials established that the turn back was likely made while the aircraft was under manual control and not the autopilot.

KL ATSC operation was normal with no significant observation until the handover to Viet Nam ATC. Being *the accepting unit*, HCM ACC did not notify *the transferring unit* (KL ATSC) when two-way communication was not established with MH370 within five minutes of the estimated time of the transfer of control point (Establishment of Communications, page 11 of Operational LOA between DCA Malaysia and Vietnam Air Traffic Management effective 1 November 2001). Likewise, KL ATSC should have taken action to contact HCM ACC, instead, relied on position information of the aircraft provided by MAS Flight Operations. By this time, the aircraft had left the range of radars visible to the KL ATSC. It is noted that about one minute elapsed from the last transmission from MH370 and the SSR being lost from the radar display. The Air Traffic Controllers of both Centres did not initiate the various emergency phases as required then, thereby delaying the activation of the alerting and Search and Rescue operations.

The PIC and FO held valid airman licences and medical certification. There is no evidence to suggest that the PIC and FO experienced recent changes or difficulties in personal relationships or that there were any conflicts or problems between them. All the flight and cabin crew were certified fit to fly and were within duty-time limits at the time of the flight and were adequately rested. There had been no financial stress or impending insolvency, recent or additional insurance coverage purchased or recent behavioural changes for the crew. The radio-telephony communications conducted by the PIC and the FO with the Air Traffic Controllers conformed to the routine procedure and no evidence of anxiety or stress was detected in the communications.

The aircraft maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures, except for the instance of the SSFDR ULB battery which had expired. The aircraft had a valid Certificate of Airworthiness and was airworthy when released for the flight and there was no record or report of any defect or malfunction in the aircraft that could have contributed to the event. Although it cannot be conclusively ruled out that an aircraft or system malfunction was a cause, based on the limited evidence available, it is more likely that the loss of communications (VHF and HF communications, ACARS, SATCOM and Transponder) prior to the diversion is due to the systems being manually turned off or power interrupted to them or additionally in the case of VHF and HF, not used, whether with intent or otherwise. No ELT signal from the aircraft was reported by the Search and Rescue agencies or any other aircraft. The SATCOM data indicated that the aircraft was airborne for more than 7 hours suggesting that the autopilot was probably functioning, at least in the basic modes, for the aircraft to be flown for such a long duration. This in turn suggests that the air and inertial data were probably available to the autopilot system and/or the crew. The inter-dependency of operation of the various aircraft systems suggests that significant parts of the aircraft electrical power system were likely to be functioning throughout the flight. The analysis of the relevant aircraft systems taking into account the route followed by the aircraft and the height at which it flew, constrained by its performance and range capability, does not suggest a mechanical problem with the aircraft's airframe, control systems, fuel or engines.

Except for the first report, the ACARS reports normally sent every 30 minutes by the SATCOM system were not received. Data from the last seven SATCOM 'handshakes' were used to help establish the approximate path of the aircraft over the Indian Ocean. The initial log-on request and the hourly pings have been termed as 'handshakes'. SATCOM transmissions indicated that a link was available from 1825 UTC on 07 March 2014 to 0011 UTC on 08 March 2014 although not used for any voice, ACARS or other data services apart from two unanswered ground-to-air telephone calls. Two log-ons, at 1825 UTC (07 March 2014) and 0019 UTC (08 March 2014), were initiated by the aircraft most likely due to power interruptions to the SATCOM avionics. The power interruption leading up to 1825 UTC was probably due to power bus cycling, the reason for it being unknown. The power interruption leading up to 0019 UTC was probably due to low fuel at this time resulting in the loss of both engines and their respective generators. There was probably enough fuel for the APU to start up and run long enough for its generator to power the SATCOM avionics to initiate a log-on request.

To date, the main wreckage of MH370 has still not been found despite a 4-year search in the South Indian Ocean. However, items of debris possibly from MH370, have been found as far north as the eastern coast of Tanzania and far south as the eastern coast of South Africa. This is in addition to several islands and island nations off the east coast of the African continent. Of these, the flaperon, a part of the right outboard flap and a section of the left outboard flap were confirmed to be from MH370. A few other pieces of debris were determined to be almost certain from MH370 which included some cabin interior items. Damage examination on the recovered part of the right outboard flap, together with the damage found on the right flaperon has led to the conclusion that the right outboard flap was most likely in the retracted position and the right flaperon was probably at, or close to, the neutral position at the time they separated from the wing. Recovery of the cabin interior debris suggests that the aircraft was likely to have broken up. However, there is insufficient information to determine if the aircraft broke up in the air or during impact with the ocean. Apart from the above, no other information about in-flight emergencies, aircraft configuration or impact could be inferred from the nature and damage of the debris.

MH370 did not carry any cargo classified as dangerous goods. Two cargo items of interest (the Lithium ion Batteries and Mangosteens) which were carried on MH370 had also been transported via scheduled flights on MAS before and after the event. These items were packed and loaded according to standard operating procedures.

As a result of the identified issues, the investigation has issued safety recommendations to enhance the safety of the aviation system. The recommendations made address the Malaysian and foreign air traffic surveillance systems, cargo scanning, flight crew medical and training records, reporting and following-up of crew mental health, flight-following system, development of a Quick Reference for Operations Control and ELT effectiveness.

It should be recognised that there is a significant lack of evidence available to the Team to determine with any certainty the reasons that the aircraft diverted from its filed flight plan route. However, the change in flight path likely resulted from manual inputs. The lack of evidence includes the exact location and disposition of the main aircraft wreckage and the evidence that it could provide, the information recorded on the Flight Data Recorder, Cockpit Voice Recorder and other recording devices on the aircraft and the absence of any aircraft voice or data transmissions that could indicate why the aircraft flew to the Southern Indian Ocean.

Without the benefit of the examination of the aircraft wreckage and recorded flight data information, the investigation was unable to identify any plausible aircraft or systems failure mode that would lead to the observed systems deactivation, diversion from the filed flight plan route and the subsequent flight path taken by the aircraft. However, the same lack of evidence precluded the investigation from definitely eliminating that possibility. The possibility of intervention by a third party cannot be excluded either.

The disappearance of MH370 and the search effort are unprecedented in commercial aviation history. Improvements must be undertaken to ensure that this type of event is identified as soon as possible, and mechanisms are in place to track an aircraft that is not following its filed flight plan for any reason.

In recent years, several States have expended significant amounts of funds and resources searching for missing commercial aircraft in remote oceanic locations, including AF447 and MH370. In this technological epoch, the international aviation community needs to provide assurance to the travelling public that the location of current-generation commercial aircraft is always known. It is unacceptable to do otherwise.

In conclusion, the Team is unable to determine the real cause for the disappearance of MH370.

SECTION 4 - SAFETY RECOMMENDATIONS

4.1 Safety Recommendation of Preliminary Report

On 09 April 2014, the Ministry of Transport, Malaysia, issued a Preliminary Report that contained the following Safety Recommendation to the International Civil Aviation Organization (ICAO):

"It is recommended that the International Civil Aviation Organization examine the safety benefits of introducing a standard for real-time tracking of commercial air transport aircraft".

Based on the above recommendation, the ICAO Council has adopted Amendments 40 and 42 on 02 March 2016 and 27 February 2017, respectively, to the International Standards and Recommended Practices, Operation of Aircraft - International Commercial Air Transport - Aeroplanes (Annex 6, Part I to the Convention on International Civil Aviation). Excerpts of the amendments are listed below.

Amendment 40

"**6.18 Location of an aeroplane in distress**
(Applicable on 10 November 2016)

6.18.1 All aeroplanes of a maximum certificated take-off mass of over 27 000 kg for which the individual certificate of airworthiness is first issued on or after 1 January 2021, shall autonomously transmit information from which a position can be determined by the operator at least once every minute, when in distress, in accordance with Appendix 9.

6.18.2 **Recommendation.** - *All aeroplanes of a maximum certificated take-off mass of over 5 700 kg for which the individual certificate of airworthiness is first issued on or after 1 January 2021, should autonomously transmit information from which a position can be determined at least once every minute, when in distress, in accordance with Appendix 9.*

6.18.3 The operator shall make position information of a flight in distress available to the appropriate organizations, as established by the State of the Operator."

Amendment 42

"3.5 AIRCRAFT TRACKING
(Applicable on 8 November 2018)

3.5.1 The operator shall establish an aircraft tracking capability to track aeroplanes throughout its area of operations.

3.5.2 **Recommendation.** — *The operator should track the position of an aeroplane through automated reporting at least every 15 minutes for the portion(s) of the in-flight operation(s) under the following conditions:*

a) the aeroplane has a maximum certificated take-off mass of over 27 000 kg and a seating capacity greater than 19; and

b) where an ATS unit obtains aeroplane position information at greater than 15 minute intervals.

3.5.3 The operator shall track the position of an aeroplane through automated reporting at least every 15 minutes for the portion(s) of the in-flight operation(s) that is planned in an oceanic area(s) under the following conditions:

a) the aeroplane has a maximum certificated take-off mass of over 45 500 kg and a seating capacity greater than 19; and

b) where an ATS unit obtains aeroplane position information at greater than 15 minute intervals."

4.2 Safety Recommendations of this Report

As a result of the issues identified in the investigation and in order to enhance greater aviation safety and benefits, the investigation has made the following Safety Recommendations (SR) to the following organisations:

4.2.1 Department of Civil Aviation - SR #01-07

SR	Safety Recommendation
#01	To review the existing coordination procedures/establish new procedures between KL ATSC and Joint Air Traffic Control Centre (JATCC) with regard to unidentified primary target observed by the Radar Controller.
#02	To review the present Duty Roster System for KL ATSC with the objective of improving the working conditions.
#03	To develop a comprehensive *Quick Reference* on ATC actions relating to aircraft emergency to be available at all Controller working positions.
#04	Air Traffic Controllers are to be provided refresher training to ensure established procedures are always complied with.
#05	To review and enhance the training syllabi of the courses for Lead-in and On-the-job training to include ATC actions during aircraft emergencies for ATS personnel at KL ATSC.
#06	To review and introduce more stringent security measures for cargo scanning at Penang International Airport/all airports and the point of entry into airside at KLIA/all airports.
#07	To review the privileging process of the appointment of the designated aviation medical examiners on a regular basis.

4.2.2 Civil Aviation Authority of Viet Nam - SR #08 - 09

SR	Safety Recommendation
#08	To observe the provisions of the Operational Letter of Agreement between Civil Aviation Authorities of adjacent Flight Information Regions.
#09	To observe the requirement of Language Proficiency as outlined from the following document: d) ICAO Annex 1 Personnel Licencing Chapter 1 paragraph 1.2.9.2 Language Proficiency; ii) ICAO Doc 9835 AN/53 Manual on the Implementation of ICAO Language Proficiency Requirements Chapter 6 - Language Testing Criteria for Global Harmonization.

4.2.3 Malaysia Airlines Berhad - SR #10-17

SR	Safety Recommendation
#10	To ensure that the flight crew report to MAB Flight Operations of any serious ailment that can cause medical incapacitation and therapy prescribed at MAB medical facilities as well as MAB-appointed panel clinics.
#11	To ensure that the medical records of the flight crew maintained by the MAB Medical Centre to include records maintained by different panel clinics. The complete medical record of the individual flight crew shall show all visits to any panel clinics, the details of ailments and therapy prescribed.
#12	To review the process of reporting system and the action flow when flight crew and cabin crew's health may become a risk factor for the safety of the aircraft operations.
#13	The personnel manning the Flight-Following System/*Flight Explorer* should be adequately trained and qualified to enable them to provide information relating to flights to the relevant authorities and/or organisations.
#14	The current Flight-Following System/ *Flight Explorer* should be upgraded to the Global real-time Tracking System.

4.2.3 Malaysia Airlines Berhad - SR #10-17 (*cont…*)

SR	Safety Recommendation
#15	To review and introduce new security measures for cargo scanning at Penang International Airport/all airports and the point of entry into airside at KLIA/all airports.
#16	A document back-up system should be implemented on every training sorties, simulator trainings, and flight trainings completed by a trainee should have their original form submitted to the Training Department and a copy retained by the trainee in his personal training file.
#17	To develop a comprehensive *Quick Reference* for the Operations Control Centre that covers every aspect of abnormal operations/situations.

4.2.4 Malaysia Airports Holdings Berhad - SR #18

SR	Safety Recommendation
#18	To review and introduce new security procedures for the scanning of cargo at the point of entry at all airports and the point of entry into the airside at KLIA/all airports in Malaysia.

4.2.5 International Civil Aviation Organization - SR #19

SR	Safety Recommendation
#19	To review the effectiveness of current ELTs fitted to passenger aircraft and consider ways to more effectively determine the location of an aircraft that enters water. Note: The Investigation Team is cognizant of the fact that this effort is already underway.

SECTION 5 – COMMENTS TO THE REPORT AS REQUIRED BY ICAO ANNEX 13, PARAGRAPH 6.3

As required by ICAO Annex 13, paragraph 6.3, the draft Report was sent to the Accredited Representatives of the States participating in the investigation inviting their significant and substantiated comments on the Report. The following is the status of the comments received.

Organisations participating in the Investigation	**Status of Significant and Substantiated Comments**
Air Accidents Investigation Branch (AAIB) of United Kingdom	Accepted and Incorporated
Australian Transport Safety Bureau (ATSB) of Australia	Accepted and Incorporated
Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (BEA) of France	Accepted and Incorporated
Civil Aviation Administration of the People's Republic of China (CAAC)	Accepted and Incorporated
National Transportation Safety Board (NTSB) of United States of America	Accepted and Incorporated
National Transportation Safety Committee (NTSC) of Indonesia	No comments received
Transport Safety Investigation Bureau (TSIB) of Singapore (formerly Air Accident Investigation Bureau [AAIB])	Accepted and Incorporated