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Agenda Item 4: Asia/Pacific and inter-regional SAR planning, coordination and cooperation

MH370 SEARCH AND RESCUE RESPONSE – JRCC AUSTRALIA

(Presented by AUSTRALIA)

SUMMARY

This paper presents an overview of the Australian SAR response to Malaysia Airlines Flight MH370 which went missing following its departure from Kuala Lumpur, Malaysia, on the 8th March 2014 with a view towards prompting APSAR/TF/3 discussion on any issues which may improve the development of the draft Asia/Pacific Regional SAR Plan.

This paper also provides a comparison from a SAR perspective between the MH370 incident and the Air France Flight AF447 incident of 2009.

1. INTRODUCTION

1.1 Malaysia Airlines Flight MH370, a Boeing 777-200ER registered 9M-MRO with 239 persons on board, departed Kuala Lumpur, Malaysia for Beijing, China at 071641 UTC 2014 (8th March local Malaysia time). The aircraft lost contact with Air Traffic Control between Malaysia and Vietnam with radar information showing the aircraft deviating from its flight planned route 44 minutes after departure.

1.2 An analysis of radar data and subsequent satellite communication (SATCOM) system signaling messages placed the aircraft in the Australian SAR Region (SRR) along an arc in the southern part of the Indian Ocean. This arc was considered to be the location where the aircraft's fuel was exhausted.

1.3 A surface search of probable impact areas along this arc was coordinated by the Australian Maritime Safety Authority's (AMSA's) JRCC Australia in Canberra from 18th March 2014 to 28th April 2014. The search effort involved a multi-national, civil/military SAR response involving aircraft and ships from several countries including Australia, China, Japan, Malaysia, New Zealand, Republic of Korea, United Kingdom and the United States of America, plus Australian and international technical experts and liaison officers. AMSA is very grateful to all the States and their many personnel involved for their assistance and expertise.

1.4 This paper is limited to outlining the SAR response by Australia within the Australian SRR and is supported by the PowerPoint Presentation, MH370 Australian SAR Response.

2. DISCUSSION

<u>Background Information</u>

2.1 Significant basic information (all times UTC):

a) MH370 departed Kuala Lumpur, 7 March 2014 at 1641

b) 1707 – final automatically transmitted position from the aircraft

c) No radio notification from the crew of a problem

d) No radio communications from crew after 1719

e) 1722 – final ATC SSR fix

f) 1725 – deviated from flight planned route

g) 1822 – final primary radar fix

h) Satellite communications log indicated the aircraft continued to fly for another 6 hours until 0019, 8 March

i) No confirmed eye-witness reports

j) No ELT transmissions received

k) 18 March – search in Australian SRR commenced

<u>Search Challenges</u>

2.2 Numerous challenges presented to the search operation. These included:

a) Lack of available and accurate position data about MH370's actual flight resulted in vast and changing search areas. Search area changes occurred following continual analysis and refinement of the limited data available. This then involved recalculating the drift applicable to new search areas. It also incurred long transit distances for search vessels as they changed to the new search areas.

b) No distress beacon detections (ELT or others carried on board).

c) Operations in remote oceanic areas at long distances offshore. This limited the choice of suitable search aircraft assets to those which could operate with sufficient endurance to transit to and from the search areas with statutory fuel reserves yet still provide available search time on scene.

d) The elapsed time of 10 days before the search commenced within the Australian SRR, and the resulting factoring in of oceanic drift, led to large search areas and wide debris dispersal.

e) Tropical cyclones, one just prior to the search and one during, influenced oceanic drift modelling.

f) Poor weather and search conditions on a number of days.

g) Transit times for ships to reach aircraft sightings.

h) Availability of ship-borne helicopters to investigate sightings.

i) Time required for satellite imagery analysis before aircraft/ships could be tasked to investigate possible objects.

j) Multinational civil/military cooperation, coordination and communications.

k) Media appetite. Use by JRCC Australia's Media Team of social media helped keep media and public updated with search information.

l) Large amount of information submitted online and via email from the public which required processing. This included information submitted by the public globally via the internet from online crowd sourcing of satellite imagery.

m) Large amount of sea pollution contributed to difficulties for air crew ability to distinguish between the pollution objects and possible debris from MH370.

n) Availability of a detailed description of cargo carried (colour, type, etc.) to enable correlation against any floating objects sighted.

o) Availability of information regarding aircraft components which are likely to float. This information was sourced and provided by the aircraft manufacturer. Composite material components were indicated as the most likely to float following aircraft impact with the water.

p) Sustainment of large logistical requirements such as air search observers, fuel, search unit maintenance and resupply requirements, accommodation, etc.

q) Clearly defined division of responsibilities between the search and rescue function (Annex 12) and the air accident investigation search and recovery function (Annex 13).

Search Area Definition

2.3 For a missing aircraft, RCCs rely on conventional sources of information regarding the aircraft and its flight in order to calculate and construct a search plan to maximize the chance of rapidly locating and rescuing survivors. In the absence of the known ditching location, RCCs rely on information such as the last known position, altitude, speed, flight planned route and/or actual track to establish a datum as a basis for calculating a search area. In the case of MH370, due to the absence of conventional data, alternative and non-conventional sources of information were used, possibly for the first time in their application to a missing aircraft, to assist with development of search areas.

2.4 Analysis of very limited satellite communications data to and from the aircraft during the flight indicated that following the last primary radar position over the north-west Malacca Strait, the aircraft continued to fly for an additional 6 hours with information such as track, altitude and speed flown not available.

2.5 JRCC Australia and the Australian Transport Safety Bureau (ATSB) jointly determined a search area strategy correlating information from a Joint Investigation Team (JIT) located in Malaysia comprised of specialists from Malaysia, China, USA, UK and France, and other government and academic sources. Analysis work was undertaken independently, collaboratively and by consensus. The analysis process included independent validation of results.

2.6 The location of the search areas was guided by continuing and innovative analysis by the JIT of the flight and satellite communications data. The group was faced with the challenge of using data from a communications satellite system and aircraft performance data to reconstruct the flight path, in effect using a satellite communications system as a navigation tracking system. Two pieces of information recorded by a satellite ground station in Perth, Western Australia at the time of a transmission with the aircraft were used to estimate the track of the aircraft. These transmissions occurred only 7 times after loss of radar contact.

2.7 This analysis was supplemented by other information provided to the ATSB during this period including possible underwater locator beacon (ULB) and hydrophone acoustic detections. Information regarding the performance and operation of the aircraft was also considered. Over the duration of the search, search areas were relocated following further refinement and analysis by the JIT of the available data.

2.8 On 17 March 2014, when JRCC Australia assumed responsibility for the SAR effort in the Southern Ocean, the JIT had determined the initial search area to be a 600,000 km^2 area approximately 2500km south-west of Perth, Western Australia. As the search areas were refined by the JIT the search areas gradually moved towards the northeast.

Search Area Definition – Satellite System Information

2.9 This section attempts to provide a very brief overview of how satellite data was used for search area definition. A far more detailed technical explanation of the complex work undertaken is available in the ATSB report, *MH370 – Definition of Underwater Search Areas* (see reference later in this paper).

2.10 The system used during flight MH370 consisted of the Inmarsat Classic Aero ground station location at Perth, Western Australia and the Inmarsat Indian Ocean Region (IOR) I-3 satellite which uses a single global communications beam per satellite and contains no explicit information relating the mobile terminal location being available.

2.11 In order to connect to the SATCOM system the aircraft transmits a "log-on" request which is acknowledged by the ground station. Once connected, if the ground station has not heard from the aircraft within a set time, it will check that the connection is still operational by transmitting a "Log-on Interrogation" message using the aircraft's unique identifier. If the aircraft receives this, it returns a short message that it is still logged onto the network. These processes have been described as handshakes. Following the last recorded primary radar data at 1822 UTC, 7 handshakes were recorded by the ground station. The 1st handshake was initiated by the aircraft at 1825 UTC and the last (7th) handshake was initiated by the aircraft at 0019 UTC. The 2nd to 6th handshakes were initiated by the ground station.

2.12 Analyses of these transmissions were used to estimate the distance of the aircraft from the satellite and to estimate the speed and direction the aircraft was travelling relative to the satellite. A set of 7 rings were plotted on the earth's surface based on the estimated distance of the aircraft from the satellite at the handshake times and by combining these three parameters with aircraft performance constraints, a range of candidate paths were found. There is no information to locate the aircraft at any single point on a ring however knowledge of the aircraft's prior location and performance speed limitations can reduce the ring to an arc.

2.13 The 1st and 7th handshakes in the middle of a flight is not common and can occur for only a few reasons, including a power interruption to the aircraft satellite data unit (SDU), software failure, loss of critical systems or loss of link due to aircraft attitude. Analysis determined a best match for a power interruption to the SDU.

2.14 Using the remaining fuel reported at the last ACARS transmission and various assumed flight speeds and altitudes, the range of the aircraft could be estimated. Analysis confirmed that the southern corridor was the only valid solution. Analysis included use of nine previous flights of 9M-MRO and 87 other aircraft with the same SATCOM terminal equipment in the air at the same time as MH370.

2.15 The aircraft satellite transmission at 0019 UTC associated with the 7th arc was possibly triggered by power interruptions on board the aircraft caused by fuel exhaustion. The time of this transmission is consistent with the maximum flight times expected for MH370 and therefore the 7th arc is the focus of the search area.

Other information considered

2.16 Air routes and waypoints were examined to see if there was any correlation with the possible southern tracks for MH370 obtained from analysis of SATCOM data. There was insufficient evidence to positively determine whether MH370 intersected any waypoints associated with published air routes in the Southern Indian Ocean.

2.17 Low frequency hydro-acoustic signals present in the Indian Ocean were examined to check whether they could provide any information to help define the search area. These signals were recorded by hydrophones as part of the UN Comprehensive Nuclear Test Ban Treaty Organisation (CTBO) or the Integrated Marine Observing System (IMOS). Curtin University, Perth and the Australian Defence Science and Technology Organisation (DSTO) analysed these signals for any underwater sounds they could be associated with an aircraft impact on the water or implosion of wreckage as the aircraft sank. One acoustic event of interest was identified that occurred at about the time of the 7th handshake however was incompatible with the satellite to aircraft range derived from that handshake.

JRCC Drift Planning

2.18 JRCC Australia uses its own custom designed drift modelling program called Net Water Movement (NWM). For conventional searches, this program has proved a valuable asset to search planning. Results from NWM are validated and compared against another proprietary drift modelling program and also validated as soon as possible through the deployment of Self Locating Datum Marker Buoys (SLDMBs). The SLDMBs are floating devices fitted with a GPS receiver and Iridium satellite transmitter which provide water current and sea temperature information and may be deployed by aircraft or vessels. The buoys transmit their position and sea temperature regularly directly to JRCC Australia. 33 SLDMBs were deployed in this search.

2.19 Due to the magnitude of the MH370 search areas, and taking into account the lessons learned during the previous search for Air France AF447 of 2009, a drift planning working group was established to supplement standard JRCC Australia drift planning methods. Its purpose was to ensure that international best methodology and consensus drift modelling techniques were applied to the MH370 search areas with the primary aims of:

a) Providing the best possible area to locate floating debris

b) Provide the ability to conduct "Reverse" drift backwards to provide an estimated splash point, should debris from the aircraft be located.

Search Strategy Working Group (SSWG)

2.20 This group was set up within AMSA to assist JRCC Australia with provision of higher level strategic oversight and provision of continuity over different JRCC shift teams in support of the SAR effort. This group also provided ongoing consideration of inputs from analysis of MH370 satellite system information, aircraft performance and pilot human factors considerations to derive suggested splash point areas which were then passed to the drift planning working group who generated search areas based on this information.

Search Effort and Results

2.21 For the 42 days of searching coordinated by JRCC Australia in the Australian SRR search areas there were:

a) 345 flight sorties

b) 3177 total flight hours

c) Cumulative search area of 4.7 million km^2

d) 28 search aircraft used, both civil and military, from Australia, China, Japan, Malaysia, Republic of Korea and USA

e) Search vessels used, both civil merchant ships and military ships from Australia, China, Malaysia, UK and USA

2.22 No debris associated with MH370 was identified by the surface search.

Acoustic search

2.23 The ATSB was the lead agency for the search for the Underwater Locator Beacons (ULBs). On 2 April 2014, the UK defence vessel *HMS Echo*, using a hull-mounted acoustic system, reported a possible ULB detection close to the 7th arc. This detection was discounted as being an artefact of the ship's sonar equipment. On 4 April 2014, the Chinese Maritime Safety Administration vessel, *MV Haixun 01* were operating pinger detector equipment from a rescue boat which detected a pulsed signal. On 5 April 2014, the Australian Defence Vessel *Ocean Shield* equipped with a towed pinger locator (TPL) system detected an acoustic signal with further detections made on 5 and 8 April, however none were able to be repeated on a reciprocal track.

2.24 *HMS Echo* was tasked to the area of the *MV Haixun 01* detections and reported the detections were unlikely due to seafloor depth, surface noise and the equipment used. A submarine tasked to the area was unable to get any detections.

2.25 An independent analysis and review of the *Ocean Shield* acoustic signals recorded determined the signals were not consistent with the nominal performance standards of the ULB and noted, whilst unlikely, the signals could be consistent with a damaged ULB. However it was decided that an ocean floor sonar search should be performed to fully investigate the detections.

2.26 The acoustic search was also supplemented using sonobuoys with an ability to detect ULB signals which were dropped by Australian AP-3C aircraft. No acoustic detections considered to be related to ULBs were detected.

2.27 An underwater sonar survey using an autonomous underwater vehicle (AUV) started on 14 April 2014 with 30 missions completed searching an area of 860 km^2 with nil debris or wreckage detected. Further work is being carried out in an attempt to determine the likely source of the *Ocean Shield* acoustic detections.

Joint Agency Coordination Centre (JACC)

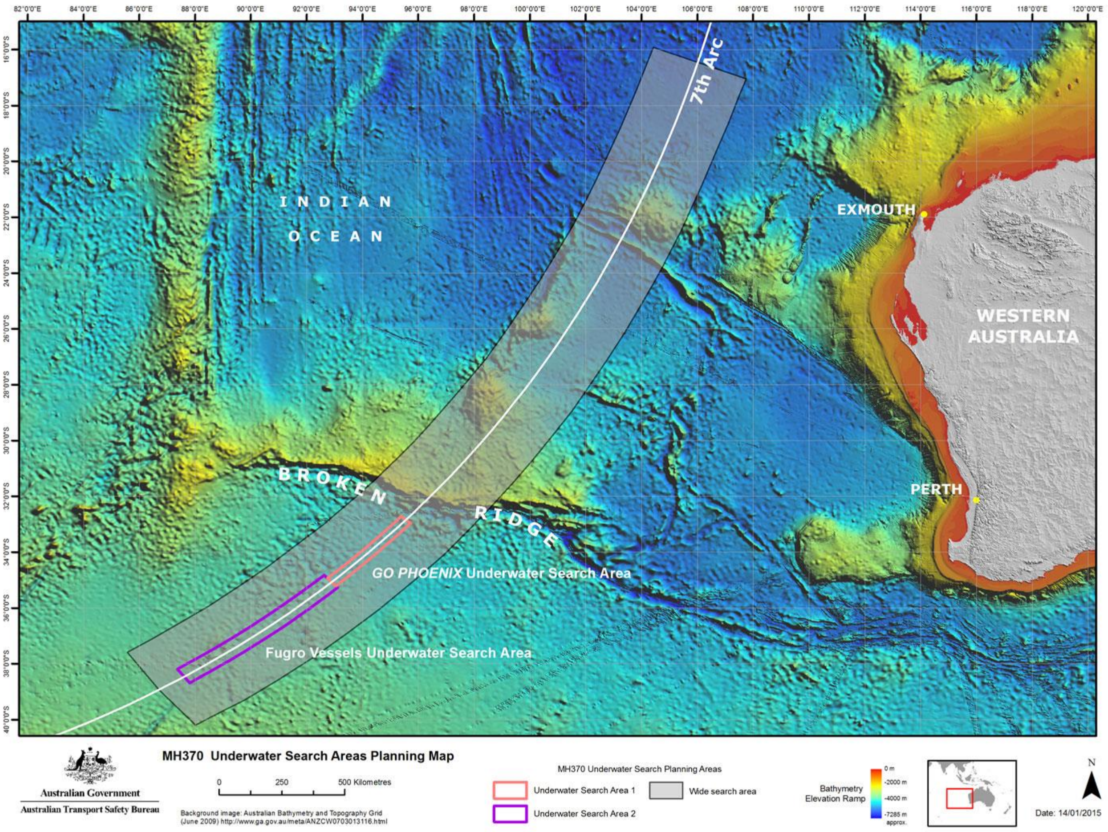
2.28 On 30 March 2014, the Prime Minister of Australia established the JACC to coordinate the Australian Government's support for the search for MH370. The purpose of the JACC is to ensure the public and other stakeholders, particularly families, are well informed about the progress of the search. The JACC works closely with the Government of Malaysia, Malaysia Airlines and other international stakeholders.

2.29 The JACC does not perform any search, recovery or investigation activities. These activities remain the responsibility of the expert agencies.

Transition from Surface Search

2.30 On 28th April 2014, the aerial search concluded and the search moved to an underwater phase. Following the completion of the ocean floor search on 28th May 2014, further work has continued to refine the analysis of both the flight and satellite data by an international team of specialists from the UK, USA and Australia working both independently and collaboratively. The team has been able to reach a consensus in identifying a priority underwater search area for the next phase of the search.

2.31 Updates to the progress of the underwater search are provided regularly on the Australian government’s Joint Agency Coordination Centre (JACC) website at www.jacc.gov.au. At the time of writing this paper, the MH370 Operational Search Update of 14 January 2015 reported that more than 14,000 square kilometres of the seafloor had been search so far and assuming no significant delays with search vessels, equipment or from the weather, the current underwater search area may be largely completed around May 2015.



Underwater search map (as at 14 January 2015)

Comparison with search for Air France Flight AF447, 2009

2.32 The search for Air France Flight AF447 which crashed into the Atlantic Ocean in 2009 was of a significant scale and presented many challenges. During the search operation for MH370, Australia has taken note of the valuable experience, lessons learned and recommendations provided in the French BEA Investigation Reports on AF447.

2.33 Attachment 1 to this paper provides a basic comparison table of the search for AF447 against the MH370 search. It provides an indication of the scale of the challenge and difficulties facing the search for MH370.

SAR System Improvement

2.34 The MH370 incident has presented a scenario not previously experienced by the global SAR community. It presents a highly valuable opportunity to the global SAR community to not only share the experiences and any lessons learned from all the States involved in the SAR response, but to also improve the existing SAR system where appropriate.

2.35 Annex 12, Search and Rescue, Recommendation 5.9.2 states:

> *"Each rescue coordination centre should prepare appraisals of actual search and rescue operations in its region. These appraisals should comprise any pertinent remarks on the procedures used and on the emergency and survival equipment, and any suggestions for improvement of those procedures and equipment. Those appraisals which are likely to be of interest to other States should be submitted to ICAO for information and dissemination as appropriate."*

2.36 Noting that the APSARTF is working towards finalising the Asia/Pacific Regional SAR Plan, due this year, the content of this paper is submitted to prompt APSAR/TF/3 discussions on any relevant additions and/or amendments to improve the Plan.

2.37 The meeting may also wish to consider listing relevant improvements for the benefit of the global SAR system in a submission to the ICAO/IMO Joint Working Group on the Harmonisation of Aeronautical and Maritime Search and Rescue.

References

2.38 Sources include:

a) Australian Maritime Safety Authority, JRCC data and media information.

- Link: http://www.amsa.gov.au/media/incidents/mh370-search.asp

b) MH370 – Definition of Underwater Search Areas, report by the Australian Transport Safety Bureau.

- Link: http://www.atsb.gov.au/media/5243942/ae-2014-054_mh370_searchareas.pdf

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) discuss relevant aspects within this paper which may assist in the development of additions and/or amendments for the improvement to the ICAO Asia/Pacific Regional SAR Plan;

c) discuss relevant aspects within this paper which may assist with improvements to the global SAR system and action the submission of a list of any such improvements to the ICAO/IMO Joint Working Group on the Harmonisation of Aeronautical and Maritime Search and Rescue for consideration, and

d) discuss any relevant matters as appropriate.

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Attachment 1 - Comparison Table – AF447 versus MH370

The following table has been compiled from information sourced from:

- the French BEA investigation reports into the accident on 1st June 2009 of, Air France Airbus A330, Flight 447, Rio de Janeiro to Paris, and
- search information from JRCC Australia for missing Malaysia Airlines Boeing 777, Flight MH370, Kuala Lumpur to Beijing, 8th March 2014.

Links:
FINAL REPORT:
http://www.bea.aero/docspa/2009/f-cp090601.en/pdf/f-cp090601.en.pdf
SEA SEARCH OPERATIONS REPORT:
http://www.bea.aero/fr/enquetes/vol.af.447/sea.search.ops.af447.05.11.2012.en.pdf
Full AF447 Investigation website:
http://www.bea.aero/en/enquetes/flight.af.447/flight.af.447.php

	AF447	**MH370**
Flight Planned Route	Was on planned route when reported missing.	Deviated significantly from planned route to take up unknown route.
Last Known Position	Was reporting by ACARS every 10 minutes. ACARS failure messages from AF447 were received by Air France including a Last Known Position (LKP).	Initial ACARS reporting up till disappeared. No further data other than satellite pings via INMARSAT.
Speed	Known = Mach 0.82 derived from ACARS message information.	Unknown.
Search Area	**Initial Search Area:** 40NM (74KM) radius centred on Last Known Position (LKP) = 17,000 square KM.	**Initial Australian Search Area:** 693,170 square KM = 40 times larger than AF447 initial search area. **Cumulative Australian search area total 18MAR to 28APR (last day of search for surface debris):** Almost 4.7 million square KM.

Surface Search	26 days. This was based on no further bodies or aircraft debris being found for the final 9 days of the search. - Aircraft search operations ceased. - Ship search operations ceased, except for French Navy vessels which remained conducting acoustic search for the ULBs.	In Australian SRR = 43 days. Australian surface search from 17MAR to 28APR14.
First Floating Debris Found	Day 5 about 70KM from LKP. **NOTE** – the BEA report states that this (distance) considerably complicated the search for the underwater wreckage.	Nil associated with MH370.
Floating Debris/Bodies	Marine pollution contributed to confusion in the early days of the search. Air searches found lots of debris – it was difficult for air crews to distinguish between marine pollution and small debris that may have been from AF447. It was not until ships arrived in the area working with aircraft that debris was able to be identified properly. About 50 bodies were recovered by ships.	Same experience with marine pollution.
“Drift Committee”	An expert working group of experts in SAR drift, oceanography, meteorology, etc attempted to estimate the crash location through “reverse drift” calculations.	Similar expert working group formed within JRCC Australia. Nil surface debris located to allow “reverse drift” calculation.
Satellite imagery	No useful results. Images from civil and military satellites were used. Aircraft flown to investigate objects detected by satellite	Similar experience for JRCC Australia.

	failed to identify debris from AF447.	
Datum Buoys deployed	9	33
Underwater Search	Duration 2 years.	To be determined.
ULB Search	No signals detected from the flight recorders.	Some acoustic detections. Some discounted, some undetermined. Further analysis work continues.
Wreckage Location	6.5NM (12KM) from LKP. Depth 3900 metres. Wreckage found following detection by AUVs of a concentration of SONAR returns. 2 further months were spent recovering the flight recorders and aircraft parts, mapping debris and recovering human remains.	Unknown. Search area depth 3800-4800 metres.
Discovery of accident site	**2APR11 (671 days or 1 year 10 months after AF447 went missing)** – concentration of Sonar returns. 3APR11 – wreckage formally identified (photos from AUV). Wreckage spread over area of 10,000 square metres. Few large parts found.	
Underwater search for flight recorders	Search for flight recorders a major challenge due to the number of items spread out on the sea floor. 1MAY11 – Flight data recorder located and raised by ROV. 2MAY11 **-** Cockpit voice recorder located. It was raised 3MAY11.	
Cost of SAR Operation	Estimated 80 million Euro	

Cost of Undersea Operation	Estimated 31 million Euro	
Total Cost of SAR and Undersea Operations	Estimated 111 million Euro	