VH-MDX Most Likely Extent (MLE) of flight

Analysis aiding the search for missing aircraft VH-MDX

3rd Edition, August 2018
(1st Edition, May 2015)

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Distribution: Public

Document purpose

The contents of this document are purely intended to clarify accident events to the best of the author's ability to offer a solid base in determining the location of VH-MDX.

⚠ **The information and data presented in this document may be inaccurate or subject to interpretation errors by the author so should not be used as evidence in legal matters**

⚠ **This document must not be used for any purpose other than to provide guidance in locating VH-MDX**

Acknowledgement

Many people have provided significant assistance to the author in producing this and other VH-MDX research documents. Many individuals have requested anonymity and the author would like to thank these people for their important input.

Special thanks go to the *National Archives of Australia* and the *Airways Museum and Civil Aviation Historical Society* for their fantastic support.

This reference paper will be subject to change as new information and data is found or errors are corrected: it is a living document

Amendments

2nd Edition: October 2015

- More pilot and ground reports included
- Grammatical corrections
- Inclusion of altimeter errors
- Use of ≈330˚M/45NM WLM final radar position as analysis commencement point

3rd Edition: August 2018

- Simpler to read format, considerable reduction in document size
- Grammatical and format changes
- Analysis commencement area is an area representing a number of definitions of the Williamtown 0936:00UTC radar position.

Abbreviations

AO	Area of Operations
AMSL	Above Mean Sea Level
ARFOR	Area Forecast
ASIB	Air Safety Investigation Branch
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATS	Air Traffic Services
BASI	Bureau of Air Safety
FIS	Flight Information Service
fpm	Feet per minute
IAS	Indicated Air Speed
ISA	International Standard Atmosphere
KIAS	Knots Indicated Air Speed
KTAS	Knots True Air Speed
kts	Knots
LSALT	Lowest Safe Altitude
MCP	Maximum Continuous Power
MLE	Most Likely Extent
MPA	Most Probable Area
MPE	Maximum Possible Extent
°M	Degrees Magnetic
NDB	Non-Directional Beacon
NVFR	Night Visual Flight Rules
MP	Manifold Pressure
MTOW	Maximum Take Off Weight
MHz	Megahertz
NM	Nautical Mile
OAT	Outside Air Temperature
PPI	Plan Position Indicator
PSR	Primary Surveillance Radar
RAAF	Royal Australian Air Force
RCC	Rescue Coordination Centre
RPM	Revolutions Per Minute
RSC	Radar Sector Controller
RSR	Route Surveillance Radar
SPI	Special Position Identification
SSR	Secondary Surveillance Radar
SYD	Sydney
°T	Degrees True
TAF	Terminal Area Forecast
TAR	Terminal *Approach* Radar (RAAF)/ Terminal *Area* Radar (Sydney)
TAS	True Air Speed
UTC	Universal Time Coordinated
WGS	World Geodetic System
WLM	Williamtown

Executive Summary

Relevant parameters were identified then used to plot a *Most Likely Extent (MLE)* boundary for missing aircraft VH-MDX. An MLE boundary is different to a Most Probable Area (MPA) in that the MLE defines an area VH-MDX is *unlikely to be significantly outside of* whilst the MPA suggests a *smaller* area viewed at the time of publication as the most probable location of VH-MDX.

The Sydney ATC derived *final* radar positions of VH-MDX were identified as being less applicable to the MLE analysis due to *multiple* wide-spread positions, uncertainty in time of positions and larger radar deviations. The earlier 0936:00UTC Williamtown radar position as defined by a spread of bearings and ranges was used as the commencement area for this analysis. This position was favoured as it was the latest radar position down the time line that exhibited a relatively narrow spread of bearings and ranges defining the position, a precise time of position and much smaller radar deviations than Sydney ATC derived radar positions.

130KIAS (Knots Indicated Air Speed) was used as the *maximum likely* airspeed of VH-MDX with a 50 knot tailwind applied. A track range of 050˚M to 080˚M representing the final radar observed track range with a +/-10˚ read-off deviation was used. The total flight time was 246 seconds from 0936:00UTC which represents a 40 second fly on time after the last received radio call from VH-MDX at 0939:26UTC.

The MLE boundary is shown below in figure 1 with a larger version contained in Annex A and is considered a reliable enough boundary to apply remote sensing resources to in order to assist search operations.

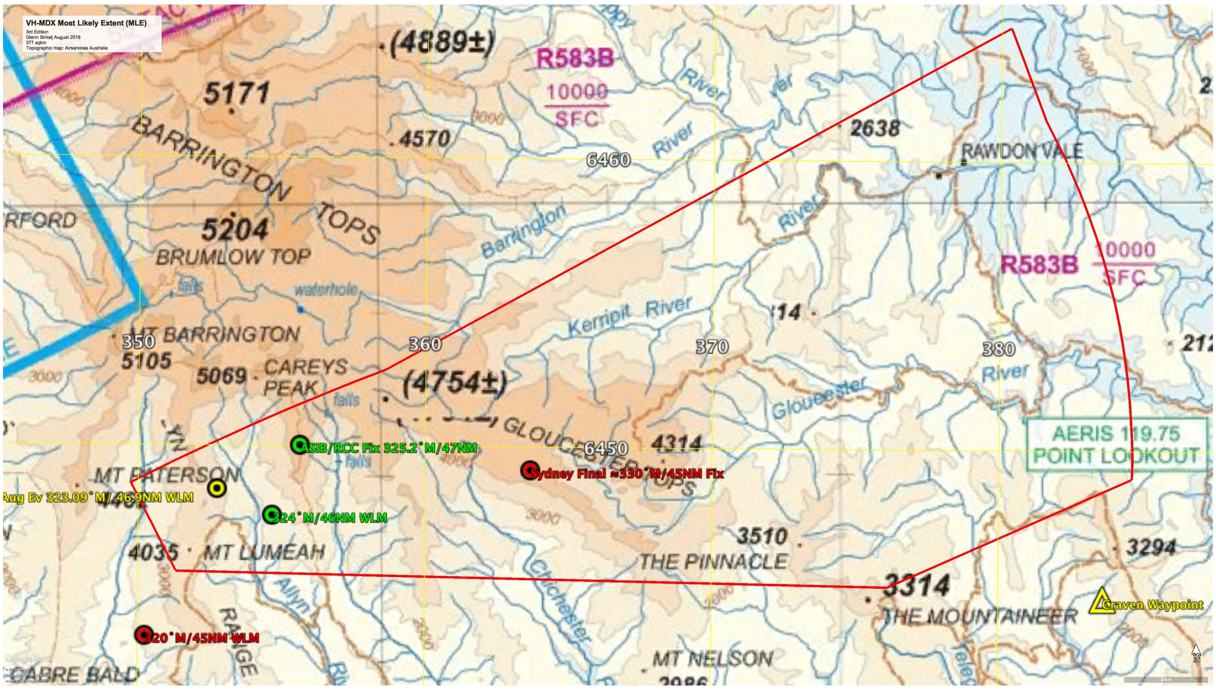

Figure 1: VH-MDX Most Likely Extent (MLE). VH-MDX is likely to be located within this boundary.

The MLE is:

- The preferred sample area for *remote sensing*
- A boundary *outside* which *full-scale* searches should not normally be conducted
- A boundary that can be used to validate or quash VH-MDX *flight path theories*.
- *377* square kilometres in area.

The MLE boundary described here is the best *current* interpretation of the information to hand and is *not* a *hard* boundary. As new information comes to hand this area may change. Search Coordinators should be aware of this and accept that future operations may be in a different location.

Contents

1. Introduction

1.1. Aim

The aim of this analysis is to generate a VH-MDX Most Likely Extent (MLE) boundary to define an area within VH-MDX is *likely* to be located within to guide search and remote sensing activities.

1.2. What is a MLE Boundary?

A MLE boundary is generated using radar position and flight path parameters that have either been *confirmed* or are viewed as being *likely* to have been apparent during the accident or, are the likely *maximum* value.

The resulting boundary is an *extent* boundary reflecting the *maximum likely* distance that VH-MDX flew from the selected radar position. Accordingly, VH-MDX is unlikely to be significantly outside the MLE boundary.

The MLE is not a statistical (stochastic) prediction of impact area but rather a boundary generated from parameters that are *confirmed* or that were *likely* apparent.

1.3. Why is a MLE needed?

The MLE is required because of convoluted and missing information regarding the VH-MDX accident. If information was correctly and accurately recorded at the time of the VH-MDX accident the aircraft would most probably have been located by now and multiple areas of interest would not be required.

A boundary is required that provides a realistic limit to VH-MDX's location. The MLE fulfils this requirement.

1.4. How is the MLE used?

The MLE defines an area that is:

- The preferred sample area for *remote sensing*
- An area *outside* which *full-scale* searches should not normally be conducted
- An area that can be used to validate or quash VH-*MDX flight path theories*.

1.5. Methodology

Information and data from VH-MDX reference papers will be used to obtain realistic parameters then develop rational assumptions and flight path scenarios.

The flight path scenarios will be plotted on Google Earth to generate a Most Likely Extent (MLE) boundary indicating the area VH-MDX is most likely located within and unlikely to be significantly outside of.

1.6. Changes to MLE Boundary

The MLE boundary is *likely* to change with time. This is the result of continual information flow, changes to the way information is interpreted and inclusion of input from subject matter experts.

2. Parameter development

2.1. Most likely flightpath

Much research and analysis has been performed by the author to verify or suggest locations of VH-MDX during the accident flight.

As of the time of writing, the most likely flightpath of VH-MDX is taken to be:

- Initially radar identified by Sydney ATC (Air Traffic Control) approximately 36NM north of Singleton NDB (Non-Directional Beacon) on the Singleton NDB/ Mount Sandon VOR (Very

High Frequency Omni Directional Range) track at 0928:45UTC, had accumulated significant ice and attempting to climb[2]

- Then i*nitially* tracked generally southwards from the above position at between approximately 8000'AMSL to 8500' AMSL (Above Mean Sea Level)[2]
- Was radar observed by Sydney ATC to have carried out a slow turn towards the east[2]
- Was radar observed by Sydney ATC to be on a track of around 120˚M at 0934:20UTC[2]
- Radar observed by RAAF Williamtown ATC to be around 323.1˚M - 325.9˚M/46.28NM - 47.20NM from the Williamtown ATC radar at 0936:00UTC[3]
- Commenced an un-commanded descent just after the previous radar position either due to ice accumulation, downdrafts or spatial disorientation or all or some of these factors together
- Accumulated additional ice around 0937:32UTC[2]
- Descended through an altitude of around 7500'AMSL at 0937:40UTC[2][5]
- Observed on Sydney ATC radar as tracking around 060˚M to 070˚M probably after the 0936:00UTC radar position [2]
- Descended through around 6500'AMSL at 0938:33UTC[2][5]
- Faded from Sydney ATC radar somewhere close to 6305'AMSL and 5495'AMSL[2]
- Descended through 5000'AMSL at 0939:26UTC (time of last received radio call from VH-MDX[5])[2]
- Impacted terrain shortly after 0939:26UTC.

2.2. Analysis commencement area

2.2.1. Overview

A position of VH-MDX is required to project likely flightpaths from. The position must exhibit suitable accuracy and precision in location and timing. These requirements mean that the last known position of VH-MDX may not necessarily be suitable. Presently, *radar* derived positional information of VH-MDX is viewed as offering the best source of VH-MDX positional information.

2.2.2. The final radar position

The *final* radar fix would be ideal to plot from given that such a fix would represent the last known position (LKP) of VH-MDX and possibly minimise the 'downrange' area. However, the following factors go against using a final radar position for this analysis:

- It has been shown that authorities recorded *multiple final,* wide-spread radar positions of VH-MDX[1][2][3]
- Recent analysis by the author has developed a reasonably defensible *final* radar *location* but the *time* of the radar position is open to debate[2]
- Being Sydney ATC derived (around double the distance to VH-MDX compared to Williamtown ATC radar) the final radar position mentioned above is subject to larger radar deviations so is a larger area than the Williamtown derived radar position prior to it.

Accordingly, the *final* radar positions of VH-MDX are less applicable for a *conservative* extent analysis such as the MLE.

2.2.3. A better alternative

Prior to this *final* radar position by approximately 2.5 to 3.0 minutes is the Williamtown ATC 0936:00UTC radar position that:

- Has a reliable time of position recorded
- Has smaller deviations (Was taken by a radar at around half the distance to VH-MDX than the radar that was likely used for the final radar position of VH-MDX)[1][3]
- Was positively identified as VH-MDX using ATCRBS (Air Traffic Control Radar Beacon System) (Transponder) SPI (Special Position Identification)/ 'Ident'[3].

This position was defined as being within a likely range of 323.1˚M - 325.9˚M and 46.28NM - 47.20NM from the Williamtown TAR and is known as the '*0936:00UTC Williamtown Radar Position*'[3]. The position was taken approximately 3.5 minutes prior to the final received radio transmission from VH-MDX. This position will be used as the commencement point for flight path projections to develop the MLE.

2.2.4.Defining the analysis commencement area

The area produced by plotting 323.1˚M - 325.9˚M/46.28NM - 47.20NM from Williamtown represents the likely area VH-MDX was within at 0936:00UTC from an *operators* point of view. This area needs to be further expanded to account for read-off and equipment deviations.

It was found when using the SURAD *Control Tower* bright display that an Air Traffic Control Officer (ATCO) could at best, determine the *bearing* of a radar target to +/-2˚ when being ‘particularly prudent’ whilst range could be determined within +/-1NM[3]. Considering the area specified in the first paragraph of this section was already developed from *a number* of possible locations for the 0936:00UTC Williamtown radar position it is best to use the *lowest* read-off deviations found (+/-2˚ and +/-1NM).

However, the span of likely position *ranges* is limited by the relationship of the ATCRBS symbols, the 44NM clutter (MTI) boundary and the radar display outer edge[3]. Accordingly, the +/-1NM range *read-off* tolerance is not applicable to this analysis.

Equipment tolerances for the SURAD Terminal Approach Radar (TAR) radar have not been confirmed[3] so the values for the similar vintage Sydney ATC Terminal Area Radar (TAR) will be used. These amount to +/-1.5˚ in azimuth and +/-1% in range[2].

Where both read-off and equipment deviations are applied they will be combined by simple averaging and added to the existing area. A magnetic variation value of 12.066˚ East (to True North) for the 1981 Williamtown TAR as predicted by Glenn Horrocks[8] will be applied to the bearing values to yield true bearings. The following area representing the 0936:00UTC Williamtown radar position results:

321.35˚M - 327.65˚M (333.42˚T- 339.72˚T)/ 45.82NM-47.67NM

This is shown as a green boundary in the image below.

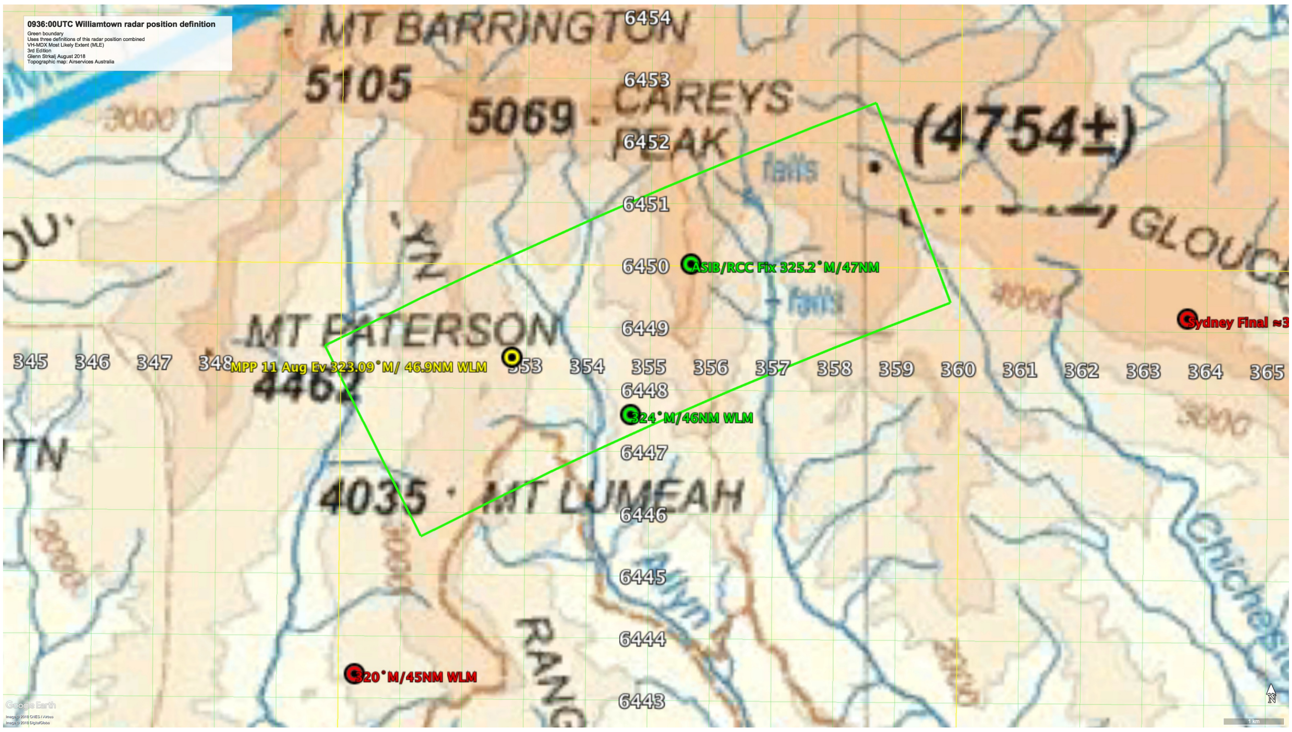

Figure 2: Definition of the 0936:00UTC Williamtown radar position. The green boundary represents the likely area VH-MDX was located within at 0936:00UTC. This green boundary will be the commencement point for the MLE analysis (Glenn strkalj 2018, plotted on Google Earth, Map: Airservices Australia).

2.3. Timing

2.3.1. Timing deviations

It was suggested that a +/-10 second tolerance is applicable to the Sydney ATS/ Williamtown ATC transcripts[4] that the 0936:00UTC radar position timing was obtained from. Given this analysis is considering extent,10 seconds will be *added* to the total analysis flight time to account for the possible deviation in transcript/recording timing.

2.3.2. Flight time

The last recorded transmission of VH-MDX was at 0939:26UTC with the pilot announcing he was at five thousand feet altitude[5]. It was probable that VH-MDX was in a steep, uncontrolled, spiralling descent by this transmission however one cannot rule out the aircraft flying on for some distance and impacting terrain at a later time.

Given the lack of radio communications received from VH-MDX after the 0939:26UTC call (from both FIS-5 and airborne aircraft in the area), the reasonably good VHF FIS-5 communications coverage in the area[4], pilot reported significant icing and primary instrument failure[5], it is likely that VH-MDX did not 'fly on' for much longer after the 0939:26UTC call.

Accordingly, an allowance of +30 seconds will be made to account for a short fly on time after the final received radio call. The deviation of +10 seconds from section 2.3.1 will also be added to this to yield a +40 second adjustment on top of the flight time from 0936:00UTC (analysis start time) to the final received radio call time of 0939:26UTC.

This yields a total flight time of 246 seconds from the 0936:00UTC radar position.

2.4. Altitude

The pilot of VH-MDX reported altitudes of:

- 'struggling to get' 8500'AMSL at 0929:10UTC
- 7500'AMSL at 0937:43UTC
- 6500'AMSL at 0938:33UTC and;
- 5000'AMSL at 0939:26UTC[5].

The altitude of VH-MDX at 0936:00UTC is not known but based on pilot altitude reports prior to and after this time VH-MDX's altitude was likely to be around 8000'AMSL.

Altitude is used in the MLE simply to determine maximum likely True Air Speed (TAS). Wind consideration in the MLE will be shown in section 2.7 to be simplified and not altitude related. Accordingly, using 8000'AMSL results in the maximum True Air Speed (TAS) for the scenario and is a conservative parameter to generate the MLE.

2.5. Speed

To generate a MLE boundary, the *fastest* speed possible *for the scenario* should be considered.

During the final approximate 15 minutes of flight, it was described how VH-MDX's Indicated Air Speed (IAS) probably did not exceed 130 knots given icing effects and a desire to minimise altitude loss or to attempt a climb[1].

This equates to a TAS of 146 knots (KTAS) when considering 8000'AMSL and ISA-5 conditions that were apparent during the accident. A constant 146 KTAS will be used throughout this analysis to generate the most *likely* flight extent.

2.6. Aircraft tracking

It was determined that VH-MDX was likely observed on Sydney ATC radar to have tracked between 060˚M and 070˚M in the final few minutes of flight[2][6]. A radar track *read-off* tolerance of +/-10˚ was found applicable to the radar display used at Sydney ATC during the VH-MDX accident [2] and this will be used to increase the final track splay by 10˚ on either side.

For the MLE, tracks of 050˚M and 080˚M will be used to form a splay from the 0936:00UTC radar position from section 2.2.4. Applying Glenn Horrocks's predicted 1981 magnetic variation for the Upper Williams River Valley of 11.732˚ East (to True North)[8] adjusts these *magnetic* tracks to *true* tracks of 061.73˚T - 091.73˚T.

2.7.Wind

It was found that the wind during the VH-MDX accident was likely to be 230˚T- 270˚T (218˚M- 258 ˚M) at 30-50 knots at 8000'AMSL[7].

As this analysis is generating the *furthest distance* VH-MDX could have flown with *likely* parameters, as a general rule the *fastest likely* wind should be used when analysing *downwind* tracks and the *slowest* expected wind should be used when analysing *upwind* tracks.

However the wind directions likely experienced by VH-MDX (218˚M- 258˚M) are aligned or almost aligned purely *downwind* with the analysis tracks (050˚M-080˚M). So for simplicity, only the fastest likely wind of 50 knots will be applied to analysis tracks as a pure downwind component.

2.8.Summary of parameters

Parameter	Value	Description
Commencement area	321.35˚M to 327.65˚M (333.42˚T- 339.72˚T) and 45.82NM to 47.67NM from the Williamtown TAR	Various definitions of the Williamtown 0936:00UTC radar position with averaged radar read-off (bearings only) and system deviations (bearings and ranges) added. Magnetic variation as determined by Glenn Horrocks applied[8].
Flight time	246 seconds from 0936:00UTC	Includes +10 seconds timing deviation
Altitude	8000 feet AMSL	Conservative constant value for extent analysis: used to determine TAS
True Air Speed (TAS)	146 knots	130KIAS probable maximum speed for scenario, converted to TAS using 8000'AMSL and ISA-5
Wind	50 knot tailwind	Maximum likely tailwind in aircraft tracking direction
Ground Speed (GS)	196 knots	3.267 NM/ min
Leg distance	13.40 NM	Based on 246 seconds flight time at 196 knots GS
Aircraft tracking	050˚M-080˚M (061.73˚T - 091.73˚T)	060˚M-070˚M with +/-10˚ track read-off buffer applied. Magnetic variation as determined by Glenn Horrocks applied[8].

3. Results

3.1.Resulting boundary

The resulting boundary represents the *Most Likely Extent (MLE)* of flight of VH-MDX: ie an area that VH-MDX is most likely resting within and is unlikely to be significantly outside of. The MLE boundary is presented in Annex A.

3.2.MLE size

The MLE is 377 square kilometres in area.

3.3. Using the MLE

The MLE is:

- The preferred sample area for *remote sensing*
- A boundary *outside* which *full-scale* searches should not normally be conducted
- A boundary that can be used to validate or quash VH-MDX *flight path theories*.

4. Conclusions

A Most Likely Extent (MLE) boundary was determined indicating the area VH-MDX is *most likely* resting within.

5. Recommendations

1. Information that suggests VH-MDX is located significantly *outside* the MLE boundary depicted in Annex A should be regarded as *unlikely*.
2. Remote sensing operations should aim to sample the *entire* area within the MLE boundary.
3. *Large scale* searches should *not* be conducted *outside* the MLE boundary without strong supporting evidence.
4. The MLE should be continually reviewed.

5. References

[1] Strkalj. G, 2015, VH-MDX Part 1: An Initial Overview, 3rd Edition, August 2015, (1st Edition, August 2014).

[2] Strkalj. G, 2017, Sydney Air Traffic Services and Radar 1981, Analysis aiding the search for missing aircraft VH-MDX, 3rd Edition. November 2017. (1st Edition, May 2014).

[3] Strkalj. G, 2015, RAAF Williamtown Air Traffic Control and radar 1981, Analysis aiding the search for missing aircraft VH-MDX, 5th Edition November, 2017, (1st Edition, May 2014).

[4] Strkalj. G, 2016, VH-MDX Communications, Analysis aiding the search for missing aircraft VH-MDX, 3rd Edition, November 2016 (1st Edition May 2014).

[5] National Archives Australia (NAA), 1981 onwards, Bureau of Air Safety Investigation (BASI), Series no C1789, Control Symbol SI/812/1036, Barcode 12067179, Aircraft Accident, VH-MDX C-210, 75km North of Singleton 9th August 1981; NSW Regional Office folio.

[6] Australian Government, 1981, various VH-MDX Air Traffic Services transcripts, Sydney ATS.

[7] Strkalj. G, 2015, VH-MDX Meteorological Conditions, Analysis aiding the search for missing aircraft VH-MDX, 2nd Edition October 2015 (First Edition May 2014).

[8] Horrocks. G, 2015, VH-MDX Background Information: Magnetic Declination, Version 2 August 2015 (Version 1 May 2014).

Annex A: Most Likely Extent (MLE) Boundary