VH-MDX Maximum Possible Extent (MPE) of Flight

Analysis aiding the search for missing aircraft VH-MDX

4th Edition, October 2019
(1st Edition: August 2014)

Glenn Strkalj

Distribution: Public

 © Glenn Strkalj 2019

Copyright and distribution of this document

Distribution of this document is solely authorised by the author. Distribution of this document to an individual or an organisation does not allow that individual or organisation to further distribute this document at their own discretion.
Provisions of the *Copyright Act 1968* apply to this document.

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

Amendments

1st Edition: August 2014

- Initial edition.

2nd Edition: November 2014

- Exact Williamtown ATC Surveillance Radar (SURAD) head geographical position confirmed by 1980's aerial imagery. Position moved 70m south from existing and tables updated with new co-ordinates. Table in Annex B referring to SURAD position now with statement: 'Actual position positively confirmed'.
- 330˚M bearing call: wording clarified to state that the Williamtown ATCO did not remember making the 330 call or looking at the PPI for this call but, that if he did make the 330 call the ATCO strongly believes the bearing would have been derived by observation of radar information.
- 330˚M bearing call: corroboration of this call with Sydney ATCO suggestions of a generally easterly track from the 320˚M/45NM radar fix.
- Inclusion of references to ASIB (Air Safety Investigation Branch).
- Minor grammatical corrections.

3rd Edition: May 2015

- General grammatical amendments
- Section 2.5: expansion on this position
- Section 2.6: expansion on this position
- Section 2.7: attempted communications with VH-MDX now in relative time
- Section 3.3: addition of +4˚/-0˚ deviation
- Section 4.1: clarification of expected aircraft altitude block
- Section 4.2: amendment and clarification of climb period, expansion on possible speed profiles
- Section 5.1: clarification that low probability of radar detection was found at the Sydney final radar position at *5000'AMSL*
- Addition of 'AMSL' where previously left out
- Recommendation: Term changed from 'highly unlikely' to 'extremely unlikely'

4th Edition: October 2019

- Significant amendment, complete re-write and re-analysis.
- No longer using the Python model by Glenn Horrocks to plot the boundary.
- Section 2.3: Initial Sydney radar position now referred to as being in the 'Moonan Brook area'.
- Research by the author has found that the wind experienced by VH-MDX over and near the Barrington Tops was unlikely to be higher than 50 knots (exclusive of gusts) and that the wind direction experienced was between 230˚T and 270˚T. These values are now used in the MPE.
- 6000'AMSL used for maximum TAS value calculation.
- Flight time now 6 minutes and 6 seconds (366 seconds) from the 320˚M/45NM 0936:00UTC radar fix.
- Radar read-off tolerances now +/-10˚ in azimuth and +3NM/ -1NM in range specific to the Williamtown 0936:00UTC fix.

- Generic SSR system (technical) tolerances now used: Bearing accuracy 0.08˚ RMS, Range accuracy: 230m.
- KTAS value now 195 KTAS (173 KTAS cruise + 22 KTAS descent allowance).

Abbreviations

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
GN	Grid North
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
ºM	Degrees Magnetic
MN	Magnetic North
MP	Manifold Pressure
MTOW	Maximum Take Off Weight
MHz	Megahertz
NDB	Non-Directional Beacon
NM	Nautical Mile
NVFR	Night Visual Flight Rules
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
SURAD	Surveillance Radar
°T	Degrees True
TAF	Terminal Area Forecast
TAR	Terminal Approach Radar
TAS	True Air Speed
TN	True North
UTC	Universal Time Coordinated
WGS	World Geodetic System

Contents

Abbreviations **5**

Executive Summary **7**

1. Introduction **8**
1.1. Aim **8**
1.2. What is a MPE Boundary? **8**
1.3. Why is a MPE needed? **8**
1.4. How is the MPE used? **8**
1.5. Methodology **8**
1.6. Changes to MPE Boundary **8**

2. Parameter development **9**
2.1. Most likely flightpath **9**
2.2. Analysis commencement area **9**
2.2.1. Overview 9
2.2.2. Final radar fix 9
2.2.3. A better alternative 10
2.2.4. Radar read-off tolerances 10
2.2.5. Radar system tolerances 11
2.2.6. Resulting area 11
2.3. Timing **12**
2.3.1. Timing deviations 12
2.3.2. Flight Time 12
2.4. Altitude **13**
2.5. Speed **13**
2.6. Aircraft tracking **15**
2.7. Wind **15**
2.8. Magnetic variation **15**
2.9. Summary of Parameters **16**

3. Results **17**
3.1. Resulting boundary **17**
3.2. MPE size **17**
3.3. Using the MPE **17**

4. Conclusions **17**

5. Recommendations **18**

6. References **18**

Annex A: VH-MDX Maximum Possible Extent of flight boundary map **19**

Executive Summary

Historically, search and investigative resources have been applied to VH-MDX in highly dispersed geographic areas. The author identified that a tool was needed to guide decision making to resource allocation in order to avoid ineffective or wasteful activities.

The aim of this analysis was to generate a boundary within which VH-MDX is *almost definitely* located within to limit resource allocation: i.e. a VH-MDX Maximum Possible Extent (MPE) boundary.

The MPE is *not* a statistical (stochastic) prediction of where VH-MDX is likely to be located but rather, a boundary containing the vast majority of possible locations VH-MDX may be at based on parameters that are either *confirmed* or the maximum expected during the accident flight.

Rather than using likely or probable parameters, this analysis used *maximum expected* parameters to ensure capture of all possible flight paths of VH-MDX.

It was assumed VH-MDX had engine power applied for a climb but maintained a lower attitude that resulted in a high power descent. This was to ensure the most extreme flight path displacement case was captured.

The 0936:00UTC 320˚M/ 45NM radar fix by Williamtown ATC was used as the flight path commencement area as this fix was found to be the most most reliable and best defined *latest* radar position of VH-MDX available for the MPE. Maximum read-off tolerances were applied to this fix. Although not the 'final' radar fix of VH-MDX this fix was the most appropriate and defensible to be used for the MPE.

Wind values obtained from defensible sources were applied in a manner that resulted in maximum flight extent.

Flight time was set to 5 minutes and 56 seconds (356 seconds) after the 320˚M/45NM fix. Such a flight time interval encompasses the 5 minutes and 20 seconds to no Williamtown radar returns observed and 4 minutes and 38 seconds to no communications response from VH-MDX. It was also shown that by this time interval and disregarding terrain, VH-MDX would be close to sea level and that when considering the terrain in the MPE area, it was likely VH-MDX contacted terrain much earlier.

The resulting MPE encompasses 8251 square kilometres and indicates the maximum possible extent that VH-MDX could have travelled. VH-MDX is *almost definitely* located within the MPE boundary.

The following recommendations were made:

1. Information which suggests that VH-MDX is located significantly *outside* the boundary depicted in Annex A should be regarded as *highly unlikely*.
2. Searches for VH-MDX should not be conducted outside this boundary.
3. The MPE should be reviewed in the future.

A map of the MPE can be found in Annex A.

.

1. Introduction

1.1. Aim

The aim of this analysis is to generate a boundary within which VH-MDX is *almost definitely* located within to limit resource allocation: i.e. a VH-MDX Maximum Possible Extent (MPE) boundary.

1.2. What is a MPE Boundary?

A MPE boundary is generated using radar fix and flight path parameters that:

- Are the maximum possible expected for the scenario considered and;
- Have been *confirmed* or are highly defensible and;
- Have maximum tolerances applied to them.

Using m*aximum* tolerances will account for the vast majority of possible flight scenarios.

The resulting boundary is an *extent* boundary that considers all possible flight paths and the maximum possible extent of those flight paths. Accordingly, VH-MDX is *extremely unlikely* to be *outside* the MPE boundary.

The MPE is *not* a statistical (stochastic) prediction of where VH-MDX is likely to be located but rather, a boundary containing the vast majority of possible locations VH-MDX may be at based on parameters that are either *confirmed* or the maximum expected during the accident flight.

1.3. Why is a MPE needed?

If more accurate information of VH-MDX's last known position was available, VH-MDX would most probably have been located by now and multiple areas of interest would not be required.

Over the years, search and investigative resources have been applied to VH-MDX in highly dispersed geographic areas. A tool is needed to guide decision making to resource allocation to avoid ineffective or wasteful activities.

An MPE boundary provides a *maximum* limit to VH-MDX's potential location. The MPE can be used to determine the scale of resource allocation or indeed if any resources are applied at all in response to suggestions of VH-MDX being located in a particular location.

1.4. How is the MPE used?

The MPE is a coarse filter. If an area of interest is outside the MPE boundary then resources should *not normally* be allocated.

1.5. Methodology

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

The flight path scenarios will be plotted which will result in a *Maximum Possible Extent (MPE)* boundary indicating the area VH-MDX is *extremely unlikely* to be located *outside of*.

1.6. Changes to MPE Boundary

The MPE boundary may 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. However the MPE boundary is less likely to significantly change than the Most Likely Extent (MLE) and Most Probable Area (MPA).

2. Parameter development

2.1. Most likely flightpath

Significant research and analysis has been performed by the author to verify or suggest locations of VH-MDX during the accident flight. At the time of writing, the most likely flightpath of VH-MDX is taken to be:

- 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 attempted to climb[1][2][4]
- Then *initially* tracked generally southwards from the above fix at between approximately 8000'AMSL to 8500' AMSL (Above Mean Sea Level)[1][2][4]
- Was radar observed by Sydney ATC to have carried out a slow turn towards the east[1][2]
- Was radar observed by Sydney ATC to be on a track of around 120°M at 0934:20UTC[1][2]
- Radar observed by RAAF Williamtown ATC to be around 321.34°M - 326.98°M (333.41°T- 339.05°T)/ 45.82NM-47.67NM from the Williamtown ATC radar at 0936:00UTC[3][5]
- Entered an un-commanded descent just after the radar fix in the dot point above either due to ice accumulation, downdrafts or spatial disorientation or some or all of these factors in combination[1][2][4]
- Accumulated additional ice around 0937:32UTC[1][5]
- Descended through an altitude of around 7500'AMSL at 0937:40UTC[1][5]
- Observed on Sydney ATC radar as tracking around 060°M to 070°M probably after the 0936:00UTC radar fix [2]
- Descended through approximately 6500'AMSL at 0938:33UTC[1][5]
- Faded from Sydney ATC radar between approximately 6305'AMSL and 5495'AMSL (Extreme range) or 6065'AMSL (0938:42UTC) and 5885'AMSL (0938:48UTC) (adjusted *probable* range)[2].
- Descended through approximately 5000'AMSL at 0939:26UTC (time of last received radio call from VH-MDX[1][5])
- Contacted terrain shortly after 0939:26UTC[1].

2.2. Analysis commencement area

2.2.1. Overview

A suitably accurate and precise location of VH-MDX is required to project likely flightpaths from to generate the MPE. Presently, *radar* derived information of VH-MDX is viewed as offering the best source of VH-MDX location information. Despite this, there are multiple radar derived last known positions (LKP) of VH-MDX[2] and these must be analysed to determine if they are adequately accurate enough for the MPE analysis.

2.2.2. Final radar fix

A *final* radar fix of VH-MDX would be ideal to project from given that it would represent the LKP of VH-MDX and possibly minimise the 'downrange' area. However, the following factors go against using one of the final radar fixes for this analysis:

- It has been shown that authorities recorded *multiple definitions* of *final* radar fixes of VH-MDX that were displaced from each other by significant distances[1][2][3]
- Recent analysis by the author has developed a defensible *final* radar *fade location* but the exact *time* of the radar fix is open to debate[2]
- Being Sydney ATC radar derived and therefore around double the distance to VH-MDX compared to Williamtown ATC radar, the final radar fade fix mentioned above is subject to larger radar deviations so, is a larger area than the Williamtown derived radar fix prior to it.

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

2.2.3. A better alternative

Approximately 2.5 to 3.0 minutes prior to the *final* radar *fade* fixes discussed in the previous section is the *Williamtown ATC 0936:00UTC radar fix* stated to be at 320˚M/ 45NM from Williamtown that:

- Has a reliable fix time recorded
- Has smaller deviations (Was taken by a radar at around half the distance to VH-MDX than the radar used for the final radar fix of VH-MDX)[1][3]
- Was positively identified as being VH-MDX using ATCRBS (Air Traffic Control Radar Beacon System) (Transponder) SPI (Special Position Identification)/ 'Ident' triangle and Mode A SSR (Secondary Surveillance Radar) symbol (likely a circle) superimposed over each other[3].
- Williamtown ATC radar was configured as a TAR thus, having a sweep rate much faster than the Sydney RSR's (faster display update of 4 seconds vs. 12 seconds)[3]
- VH-MDX at 45NM was in very close proximity to the 48NM outer edge of the radar display (Plan Position Indicator-PPI) where the compass rose was located thus, bearing read-off and range determination can be regarded as simple and precise[3]
- Permanent clutter of the Barrington and Gloucester Tops was displayed unsuppressed, outside of 44NM in the north-west sector and was a notable, continuous feature on the PPI[3]. VH-MDX was identified within this clutter accordingly, a gross error check of position exists (VH-MDX must have been between 44NM and 48NM in the north-west sector between 310˚M and 330˚M)[3]
- The maximum read-off tolerance in range can be further refined as the ATCO observed *full* and *unclipped* SSR symbology[3]; so, VH-MDX was not more than a maximum distance of approximately 47NM to preserve SSR symbol integrity[3]
- Sydney Radar passed on a position of 320˚M/46NM approximately 1.5 minutes previous that grossly aligns with the Williamtown ATCO's position[3]

Considering the points above, the 320˚M/45NM Williamtown ATC radar fix is the most reliable and best defined *latest* radar position of VH-MDX available for the MPE.

This radar fix has been analysed by the author and a *likely* geographical definition determined[3] however, for an extent analysis larger tolerances which represent all possible fix locations should be used. This will determined in the next section.

This fix was taken approximately 3 minutes and 26 seconds prior to the final received radio transmission from VH-MDX and will be used as the commencement point for flight path projections to develop the MPE.

2.2.4. Radar read-off tolerances

It was described how the following tolerances are applicable to Williamtown SURAD (Surveillance Radar) operations involving the Tower radar display (PPI) used during the VH-MDX accident)[3]:

- +/-10˚ bearing accuracy with a *quick visual* assessment
- +/-5˚ bearing accuracy with a *quick 'rule off'*
- +/-2˚-3˚ bearing accuracy when assessing *with care*
- +/-2˚ bearing accuracy when being *particularly prudent*
- +/-1NM in range.

For a maximum extent type of analysis, using the quick visual assessment value in *azimuth* of +/-10˚ is prudent to account for the crudest radar paint position assessment.

Regarding read-off *range* tolerance specifically relating to the Williamtown 0936:00UTC 320˚M/45NM fix, this was determined to be +2NM/-0NM based on ATCO interviews and cross checking VH-MDX returns with permanent terrain clutter[3].

To include all possibilities in range of this fix, a further step can be taken. VH-MDX returns were confidently stated to be within permanent terrain clutter (i.e. outside 44NM) and inside 48NM (scope outer edge). Applying this range of 44NM to 48NM or in a tolerance form, +3NM/ -1NM, accounts for all possibilities in range.

Figure 1 below presents a sketch of the Williamtown PPI, radar symbols and clutter.

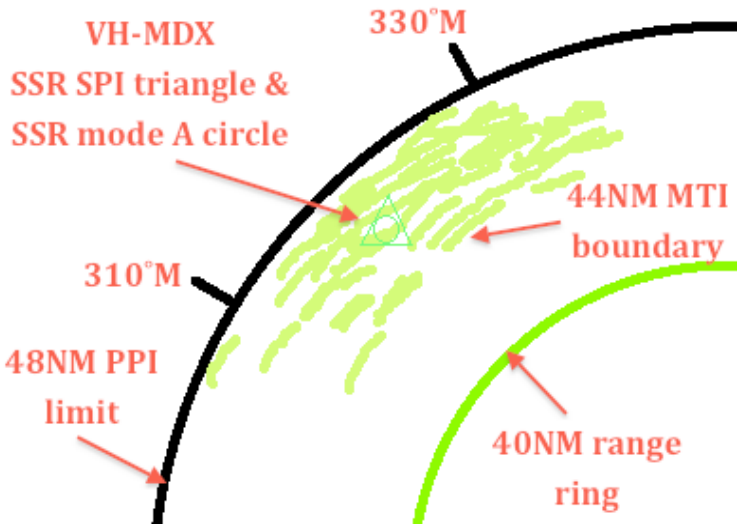

Figure 1: Reported position of the 320˚M/45NM fix. Despite the permanent terrain clutter, the SSR symbology of the returns were readily apparent to the Williamtown ATCO because of shape. Bearing read-off was simple given the proximity of the returns to the compass rose on the outer edge. The compass rose had 5˚ markings numbered every 10˚. A 44NM MTI filter boundary and 48NM outer edge brackets the range of the returns from the radar head rather simply as well. SPI ident was observed minimising chances of miss-identification. This radar fix is the most reliable and best defined *latest* radar position of VH-MDX available for the MPE (Image: Strkalj 2014).

2.2.5. Radar system tolerances

Radar system (technical) tolerances for the Williamtown SURAD SSR system have not been confirmed. Despite this, the generic accuracy of the non-monopulse SSR system SURAD was likely to be is available:

- Bearing accuracy approx 0.08˚ RMS
- Range accuracy: approx 230m RMS[11]

The system (technical) tolerances of the Williamtown SURAD SSR are so comparatively small to the read-off tolerances that they would have no pragmatic effect on the results.

Because of this, the system tolerances will not be used and only the read-off tolerances will be applied to the analysis.

2.2.6. Resulting area

When applying the radar read-off tolerances to the 320˚M/45NM from Williamtown position along with the predicted magnetic variation for the SURAD radar head in 1981, the area in Figure 2 shown on the next page is made.

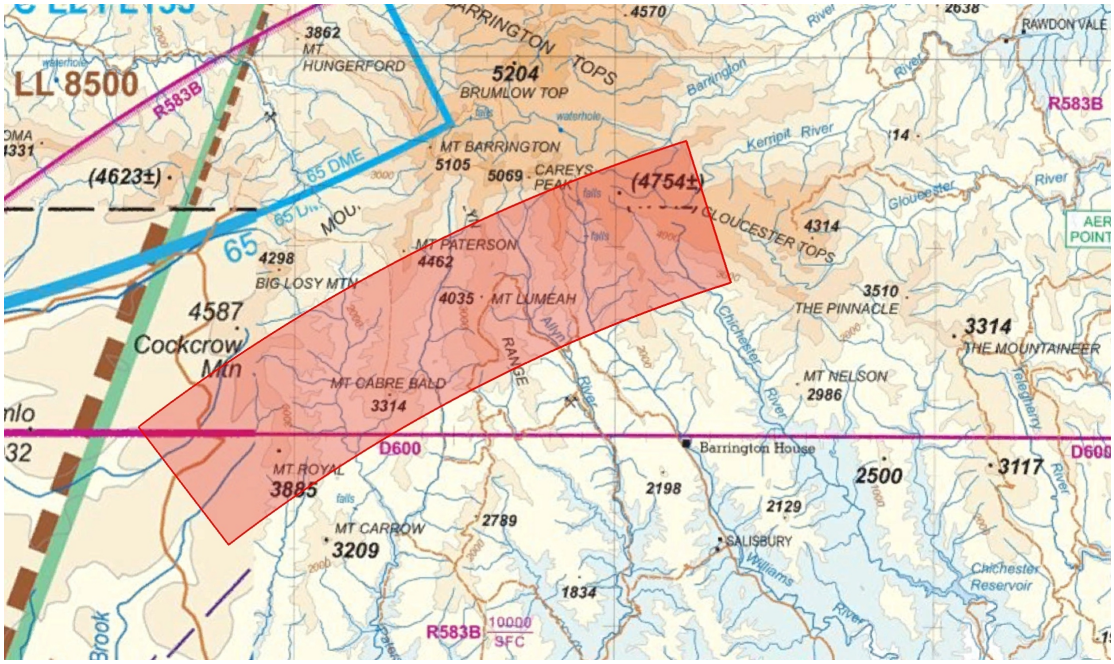

Figure 2: Williamtown 320˚M/ 45NM at 0936:00UTC with read-off errors applied. This definition of this fix offers a conservative starting point from which projections representative of all flight path possibilities can be made. Read-off errors used: Azimuth +/-10˚, Range: +3NM/ -1NM.

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[3] that the 0936:00UTC Williamtown radar fix 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 deviations to the transcribed time.

2.3.2. Flight Time

The last recorded transmission of VH-MDX was at 0939:26UTC, approximately 3 minutes 26 seconds after the 320˚M/45NM fix[5], with the pilot announcing he was at five thousand feet altitude[5]. It is viewed probable that VH-MDX was in a steep, uncontrolled, spiralling descent soon after this transmission however one cannot rule out the aircraft flying on for some distance and impacting terrain at a later time.

The Williamtown ATCO consciously overviewed the radar display at 0941:20UTC, approximately 5 minutes and 20 seconds after the 320˚M/45NM fix and found no radar returns from VH-MDX[3][5]. The first communications attempt of FIS-5 with VH-MDX following the 5000' call acknowledgement was at 0940:38UTC, approximately 4 minutes and 38 seconds after the 320˚M/45NM fix[4][5].

Radar and radio communications coverage may have been compromised by terrain shielding as a result of flight at ever decreasing altitudes and it is acknowledged that basing terrain contact time on no-communications or radar fade is *not* a completely defensible approach.

Considering the ever increasing final rates of descent (almost 2000fpm)[2][5] and terrain elevation in the general area of the Barrington Tops, it is unlikely VH-MDX flew for more than 2 minutes after the 5000' call at 0939:26UTC as it would be probable that VH-MDX was approaching 1000'AMSL by this stage and would have likely impacted the generally much higher terrain in the area.

Considering descent at 2000fpm for 2 minutes 30 seconds after the final received radio call and disregarding terrain, VH-MDX would be close to Sea Level. If considering the terrain in the MPE area, it was likely VH-MDX contacted terrain much earlier.

Accordingly, a time interval of 2 minutes 30 seconds after the final ‘5000’ call will be considered. This equates to 5 minutes and 56 seconds (356 seconds) after the 320°M/ 45NM fix.

Such a flight time interval encompasses the 5 minutes and 20 seconds to no radar returns observed at Williamtown and 4 minutes and 38 seconds to no communications response by VH-MDX to FIS-5 radio calls.

2.4. Altitude

Altitude is used in the MPE solely to determine the maximum possible True Air Speed (TAS) during the analysis period. If maintaining the same engine power setting, TAS increases with aircraft altitude.

But as VH-MDX used a normally aspirated (non-turbocharged) engine that at some altitude is unable to maintain power with altitude, the TAS for a particular power setting peaks at a particular altitude. In the case of VH-MDX TAS peaks at approximately 6000’AMSL in ISA conditions[9].

Regarding wind, the strongest and weakest wind can be independently selected from a range of altitudes VH-MDX flew at during the analysis period to yield the furthest flight distance. Accordingly, this will be treated independently of altitude selection to calculate TAS.

The altitude of VH-MDX at 0936:00UTC cannot be confirmed however, it was shown that VH-MDX was at around 8000’AMSL during the 0936:00UTC radar fix[3] and at lower altitudes following this fix[2][4]. The pilot of VH-MDX reported the following altitudes via radio transmissions[5]:

- ‘struggling to get’ 8500’AMSL at 0929:10UTC
- 7500’AMSL at 0937:40UTC
- 6500’AMSL at 0938:33UTC and;
- 5000’AMSL at 0939:26UTC.

It can be seen that VH-MDX spent a reasonable amount of time within +/-1000’ of 6000’AMSL. This coupled with 6000’AMSL ISA being the altitude resulting in the highest TAS VH-MDX could achieve solidifies the use of 6000’AMSL as the altitude TAS will be calculated at.

Although ISA-5 conditions were found to be apparent in the Barrington Tops area during the flight[7], assuming ISA will place a small conservative (faster TAS) buffer in the analysis.

2.5. Speed

To determine the maximum distance (extent) possibly travelled, the *fastest* IAS (Indicated Air Speed) expected to be flown for the *situation* must be determined.

Communications transcripts suggest VH-MDX was *attempting* to climb during most of the period from 0923:52UTC to 0929:11UTC[1]. From 0938:29UTC, the pilot of VH-MDX made radio calls indicating descent[1].

Given the reported issues associated with the artificial horizon onboard VH-MDX, it cannot be confidently concluded exactly what profile was apparent during the descent phase or even when descent actually commenced. Descent may have been the result of:

- Climb attitude set using normal or best performance climb speeds but an inability to climb due to any combination of icing, downdrafts and turbulence (slow speed case)
- An attitude lower than the climb attitude set, for the purposes of keeping speed (cruise type profile) or as a result of loss of situational awareness of the horizon coupled with any combination of icing, downdrafts and turbulence (high speed case).

The first case is presently viewed as the most probable scenario however, the latter case is possible. The pilot of VH-MDX may have been flying at a cruise type profile following the initial failed climb attempts to exit the icing area quickly. Chessor has also suggested this[10]. Indeed the pilot's intention was to: '*…. try to continue our flight plan*'[5]. Or on the other hand the lack of a correctly functioning artificial horizon could have lead to a lower attitude with higher speeds.

The most applicable scenario to the MPE analysis is the situation where Maximum Continuous Power (MCP) or takeoff power was set for climb but the aircraft descended with this power.

MCP or Takeoff power set whilst descending is a possible situation and may have eventuated because of failed primary attitude instrumentation leading to situations such as:

- Inability to establish and/or maintain a climb attitude;
- Continual pitching up and down resulting in a mean TAS approaching descent with high power TAS.

Considering a descent with climb power set will result in maximum displacement from the 320˚M/45NM fix within the scenario so, will be used for MPE analysis.

C-210 engine power is set by adjusting Manifold Pressure (MP) with the throttle and propeller RPM with a propeller pitch control lever. Three applicable climb power settings are specified:

- *Takeoff Power* setting of full throttle and 2850RPM which is rated for only 5 minutes[9].
- *Maximum Continuous Power (MCP)* setting of full throttle and 2700RPM which could be maintained *indefinitely*[9]
- Standard *cruising climb* power for the C-210 is full throttle to a maximum MP of 25" and 2550 RPM[9].

TAS values for cruising with cruising climb power set are available. At 6000' AMSL in ISA, around 24" of MP is possible so, setting full throttle and 2550RPM at this altitude yields engine output power to establish a ≈78% cruise power setting[9]. 173KTAS would be theoretically achieved in *level* flight[9].

As the situation became desperate, the pilot of VH-MDX would likely have extracted maximum or close to maximum power output of the engine in an attempt to climb. This would involve leaving full throttle applied and setting the propeller RPM to either:

- Maximum Continuous Power (MCP) setting of 2700RPM which could be maintained *indefinitely*[9]
- Takeoff Power setting of 2850RPM which is rated for only 5 minutes[9].

There are no KTAS figures available for either level or descending flight with either MCP or takeoff power set[9] as these are not normal cruise or descent power settings. As a result, some allowance must be made to the ≈78% cruise TAS to account for MCP or takeoff power being set whilst descending.

The author believes an additive of 20 KIAS is realistic considering:

- VH-MDX being at between 5000' and 8000' altitude for most of the analysed leg would mean that advancement of the propeller RPM would likely result in minimal power and therefore TAS increase.
- Aircraft manufacturer performance figures are normally inflated over those achieved by the average pilot in an aged aircraft (meaning a pragmatic cruise TAS of less than 173KTAS would be realised at 78% power setting at 6000' ISA) and that this difference could account for application of MCP or take off power.
- Experience with C-210 cruise powered descents of the author and author's colleagues suggest IAS increases of around 15-20 knots over cruise IAS.

20 KIAS converted to KTAS at 6000' in ISA equals 22 KTAS and will be added to the 173 KTAS cruise value.

A TAS of 195 knots will be used for Maximum Possible Extent analysis.

2.6. Aircraft tracking

It was found that VH-MDX was observed on Sydney ATC radar to have tracked between 060˚M and 070˚M in the final few minutes of flight[2][6]. This timeframe encompasses flight from the 320˚M/45NM fix[2][3] so, this knowledge could be used in the MPE to consider tracks only in a generally easterly direction.

However, it is *not* the objective of the MPE analysis to suggest specific small areas of interest but rather, to define a boundary that defines all possible flight paths and the maximum possible extent of those flight paths.

Accordingly, tracking in all directions from the 320˚M/45NM fix should be applied in the analysis.

Tracks in all directions (360˚) from every part of the 320˚M/45NM fix boundary will be projected. In a Maximum Possible Extent analysis, the tracking contributing the largest distances flown from the 320˚M/45NM fix are *straight* courses from this fix. As a result, curved paths do not need to be considered.

2.7. Wind

It was found that the 8000'AMSL wind during the VH-MDX accident was likely to be 230˚T-270˚T (218˚M- 258˚M) at 30-50 knots[7]. it was shown probable that wind speed generally increased with increasing altitude during the VH-MDX accident[7][12].

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.

Wind flow over a mountain range may cause modifications to local and downstream wind velocities, induce turbulent flow and generate stagnant (low to no wind) zones. Such effects will *not* be accounted for in this analysis. Basic, constant velocity winds will be used.

This analysis will use the most appropriate wind direction and speed from the 230˚T- 270˚T (218˚M- 258˚M) at 30-50 knots likely wind range to achieve the *furthest distance of flight* with the remaining parameters.

2.8. Magnetic variation

Magnetic variation adjustments are required for a number of parameters. Glenn Horrocks' Australian Geomagnetic Reference Field (AGF) Magnetic Variation / Geoscience Australia based prediction for the Barrington Tops in 1981[8] will be used.

2.9. Summary of Parameters

Figure 3 below contains a summary of parameters used in the MPE analysis.

Parameter	Value	Description
Commencement area	• 320˚M/45NM 0936:00UTC radar fix + • Maximum *azimuth* read-off deviation of +/-10˚ (*quick visual* assessment) + • Maximum *range* read-off deviation *+3NM/ -1NM range (limits in clutter)*	Only Read-off tolerances will be incorporated as the system (technical) tolerances are comparatively so small that they have little effect on results.
Flight time	6 minutes and 6 seconds (366 seconds) from the 320˚M/45NM 0936:00UTC radar fix	5 minutes and 56 seconds (356 seconds) flight time +10 seconds timing deviation
Altitude	6000 feet AMSL ISA	Conservative constant value for extent analysis: used to determine maximum TAS
True Air Speed (TAS)	195 knots	195 KTAS maximum speed for scenario, used as a constant speed throughout. 173kt @ 6000' ISA + 22 KTAS descent additive.
Wind	230˚T- 270˚T (218˚M- 258˚M) at 30-50 knots	Apply the most appropriate wind direction and speed from this likely wind range to achieve the *furthest distance of flight*
Ground Speed (GS)	Determined from interaction of TAS value with the wind value that results in maximum extent	Plotting of all wind and TAS combinations, selection of the results with the maximum extent.
Magnetic variation	Upper Williams River: 11.732˚E to TN/ 10.926˚E to GN WLM SURAD: 12.066˚E to TN / 11.430˚E to GN	Used to convert values between MN, GN, TN.
Aircraft tracking	In all directions from all points on the radar fix boundary	To account for *all possible* rather than likely track directions
Boundary style	Convex Hull	Smoothing of the boundary to yield a practical boundary

Figure 3: Maximum Possible Extent of flight analysis parameters. These parameters are *highly conservative* accounting for much larger deviations than have been confirmed or were likely. Such an approach ensures full capture of all possible geographical areas VH-MDX may be located within. Further, separate analysis will be carried out to define smaller areas of interest to guide search operations.

 © Glenn Strkalj 2019

3. Results

3.1. Resulting boundary

The resulting boundary represents the Maximum Possible Extent (MPE) of flight of VH-MDX: i.e. an area that VH-MDX is almost definitely resting within and unlikely to be significantly outside of. The MPE boundary is presented in Figure 4 below and a larger version in Annex A.

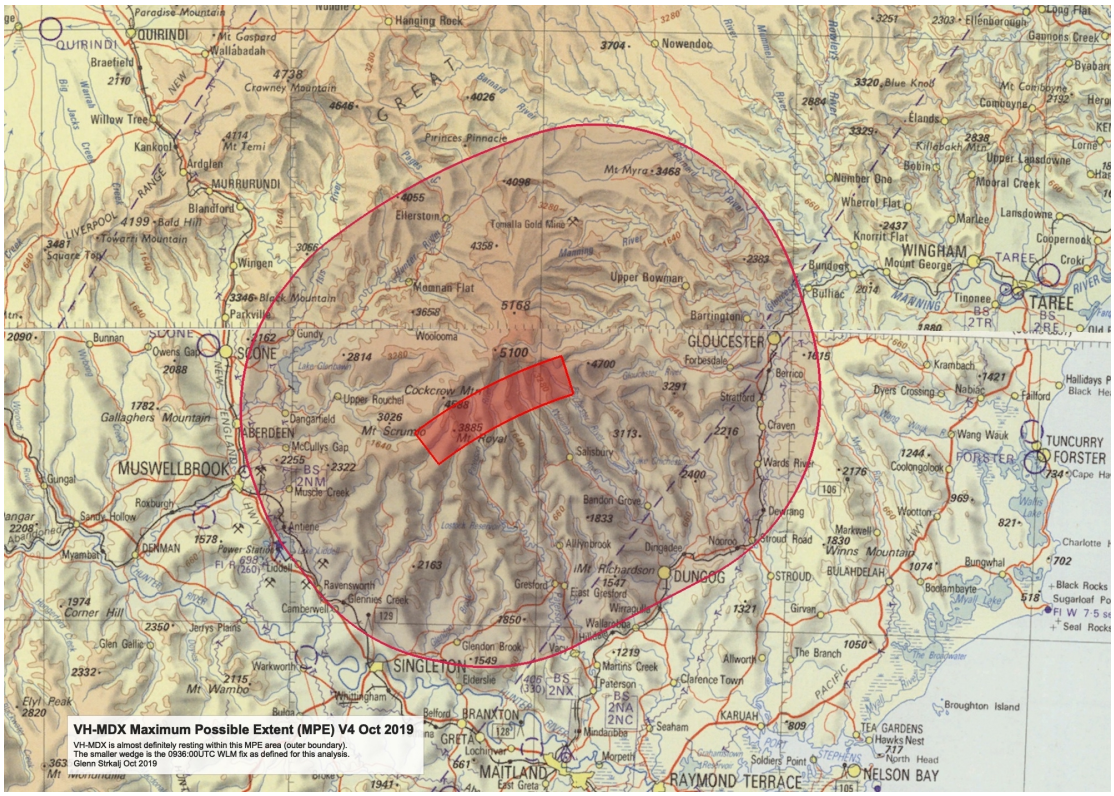

Figure 4: VH-MDX Maximum Possible Extent (MPE) of flight. VH-MDX is *almost definitely* located within the MPE boundary. It is *highly unlikely* VH-MDX is outside this boundary. The MPE offers a coarse, 'first stage' filter to determine if search and/or investigative resources should be applied or not.

3.2. MPE size

The MPE is 8251 square kilometres in area.

3.3. Using the MPE

The MPE is:

- A geographical limit to search operations (search operations outside the MPE should not be conducted).
- A boundary that can be used to validate or quash VH-MDX *flight path theories*
- The MPE is not a hard boundary: some leeway should be given close to the boundary.

4. Conclusions

A Maximum Possible Extent (MPE) boundary was determined showing where VH-MDX is *almost definitely* located. It is *highly unlikely* VH-MDX is outside this boundary. The MPE offers a coarse, 'first stage' filter to determine if search and/or investigative resources should be applied or not.

5. Recommendations

1. Information which suggests that VH-MDX is located significantly *outside* the boundary depicted in figure Annex A should be regarded as *highly unlikely*.
2. Searches for VH-MDX should not be conducted outside this boundary.
3. The MPE should be reviewed in the future.

6. 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, 4th Edition. September 2018. (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).

[9] Cessna Aircraft Company, 1976, *Pilots Operating Handbook*, *Centurion 1977 Model 210M*, Wichita, Kansas.

[10] Chessor. D, 1990, *Research into Probable Crash Sites in Barrington Tops of Cessna 210 VH-MDX*, Sunday 19:40 HRS, 9th August 1981, Draft, 25th September 1990.

[11] Stevens, M.C. *Surveillance in the Mode S Era*, CAA/IEE Symposium on ATC, London. March 1990

[12] Horrocks. G, 2015, *Analysis of the winds on 9 August 1981 in the southern Barrington Tops region*, 2nd Edition, August 2015 (1st Edition, July 2013).

Annex A: VH-MDX Maximum Possible Extent of flight boundary map

