VH-MDX Maximum Possible Extent of Flight

Analysis Aiding the Search of Aircraft VH-MDX

Version: 3rd Edition (May 2015)

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August 2014

Distribution: Public

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Document purpose

This document was drafted to support VH-MDX related operations of the individual authors, Bushwalkers Wilderness Rescue Squad (BWRS) search operations and NSW Police Rescue and Bomb Disposal Unit (NSWPRBDU) Strike Force Wittenoom.

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

Amendments:

2nd Edition

- 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

- 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'

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
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
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
ºT	Degrees True
TAF	Terminal Area Forecast
TAR	Terminal Approach Radar
TAS	True Air Speed
UTC	Universal Time Coordinated
WGS	World Geodetic System

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Executive summary

The purpose of this paper was to define *highly conservative*, but *robustly found* geographical boundaries within which VH-MDX is located. That is, to define an area where VH-MDX is definitely located; and outside that area it is impossible (or at least extremely unlikely) for VH-MDX to be located: a *Maximum Possible Extent of flight* analysis. **A map depicting Maximum Possible Extent of VH-MDX is contained in Annex A on page 25.**

The authors believed this was the first step required to locate VH-MDX following detailed background research. Narrowing down small areas of probable impact based more on assumption rather than hard facts was not the purpose of this paper: this will be done in ensuing papers.

Such a *Maximum Possible Extent of flight* analysis did not exist and was viewed by the authors as an important tool for emergency services and researchers to restrict *detailed* intelligence and search activities within defined areas to maximise resource allocation.

This was particularly relevant recently given the stimulation media has given to the general public regarding VH-MDX. Increased reports of wreckage, Google Earth images and eyewitness accounts were apparent and in many cases the locations of such reports were some distance away from the Barrington Tops area.

Highly conservative parameters and standard deviations were used to ensure no 'loss' of geographic area occurred. The 320˚M/45NM RAAF Williamtown radar fix was used as the starting point for analysis as this fix was the most accurate and reliable 'latest' fix available as was shown in *RAAF Williamtown Air Traffic Control 1981*[4].

Tolerances far beyond that suggested in previous research[4] were applied to this radar position (+/-10˚ vs. +4˚/-2˚ and +3NM/-1NM vs. +2NM/-0) for the analysis. Applied winds were also highly conservative being 225˚T-270˚T between 30 knots - 80 knots. It was assumed VH-MDX might have tracked in all directions (360˚) from the radar position.

A time interval of +6.0 minutes from the 320˚M/45NM fix was used to conservatively account for FIS-5 attempted communications (+4.5 min), no observed returns at Williamtown radar (+5.5 min), the aircraft likely being at 1000'AMSL (thus likely impacted terrain) based on rates of descent from communications (+5.5 min) and the aircraft likely being at sea level based on rates of descent (+6.0 min).

Although the pilot of VH-MDX was more likely to be flying at slower climb or cruise speeds, a descent speed based on approximately 75% cruise power plus 20 knots to account for descent attitude and Maximum Continuous Power (MCP) RPM or Takeoff Power RPM being set was used to encompass the *fastest possible* speed of the scenario (172KTAS +20 knots = 192KTAS).

The map on page page 23 was generated depicting a boundary beyond which VH-MDX would not be located. The map is a useful tool to determine the level of resources to be applied to reports or theories.

1. Introduction

1.1. Purpose

Following technical research, the first *analysis* step in resolving the VH-MDX conundrum is to define a boundary beyond which VH-MDX could not have flown outside. Such a boundary can be used by individuals, emergency services and other organisations to confidently restrict *detailed* intelligence and search activities. Additionally, such material can provide a ready reference to confidently support or quash VH-MDX flight path theories.

Recent increase of media activity regarding VH-MDX has highlighted the increased need for such an analysis. Many reports from the general public relating to wreckage, Google Earth images and eyewitness accounts have flooded in. In many cases these reports are referring to locations significantly displaced from the Barrington Tops area.

There has also been much debate of whether VH-MDX could have 'made it' to certain locations with little robust material to answer or support these suggestions.

To date, there is no known guidance material that confidently and conservatively defines the extreme possible geographical limits as to the location of VH-MDX. The purpose of this paper is to define *highly conservative*, but *robustly found* geographical boundaries within which VH-MDX is located. That is, to define an area where VH-MDX is definitely located; and outside that area it is impossible (or at least extremely unlikely) for VH-MDX to be located.

Very *broad* tolerances and assumptions will be made to account for the vast majority of scenarios possible. Finesse of particular search areas is not the objective of this paper; such an approach will be carried in ensuing papers.

1.2. Aim

The aim of this paper is to:

Provide a *highly conservative* geographical boundary defining the Maximum Possible Extent VH-MDX may have travelled to enable effective intelligence and search activities.

1.3. Methodology

Information and data from VH-MDX reference papers by one of the authors (Strkalj) will be used to develop *highly conservative* assumptions. Such information, data and assumptions will be used in flight modeling software written specifically for this task by the other author (Horrocks).

A maximum extent area of interest as to the final resting place of VH-MDX will result.

2. General overview

2.1. Intended plan and conditions

On the 9th August 1981, the pilot of VH-MDX intended to fly from Coolangatta to Bankstown generally coastal and predominantly at night[1]. The nominated flight rules were Night Visual Flight Rules (NVFR)[1] requiring flight clear of cloud. A heavy reliance on radio navigation aids would have been required to regularly and reliably obtain position fixes.

Weather conditions were a dark night with generally clear skies and strong south-westerly to westerly winds generating localised orographic clouds along the western tops of mountain ranges[1]. Accordingly, conditions were generally suitable for NVFR procedures.

From Taree NDB (Non-Directional Beacon), VH-MDX was *planned* to track to Craven (waypoint/intersection, not township), Singleton NDB then via Mount McQuoid NDB to Bankstown[1].

2.2. From Taree

After reporting overhead Taree at 0850:00UTC at 8000', VH-MDX likely tracked an initial course generally southbound from Taree NDB towards Williamtown. At some stage VH-MDX turned and tracked towards the west likely passing to the north of Craven intersection and continuing westbound rather than south-west through Craven intersection as planned.

From 0923:54UTC onwards, the pilot reports being in cloud and turbulence whilst also advising the loss of primary attitude and heading instrumentation[1]. Significant icing was also reported as being experienced[1].

VH-MDX proceeded further west in vicinity of Moonan Brook to the north-west of the Barrington Tops.

Figure 1 on the following page shows the planned track (red) and approximate, generalised actual track flown (green) to the 320˚M/45NM Williamtown radar fix at 0936:00UTC.

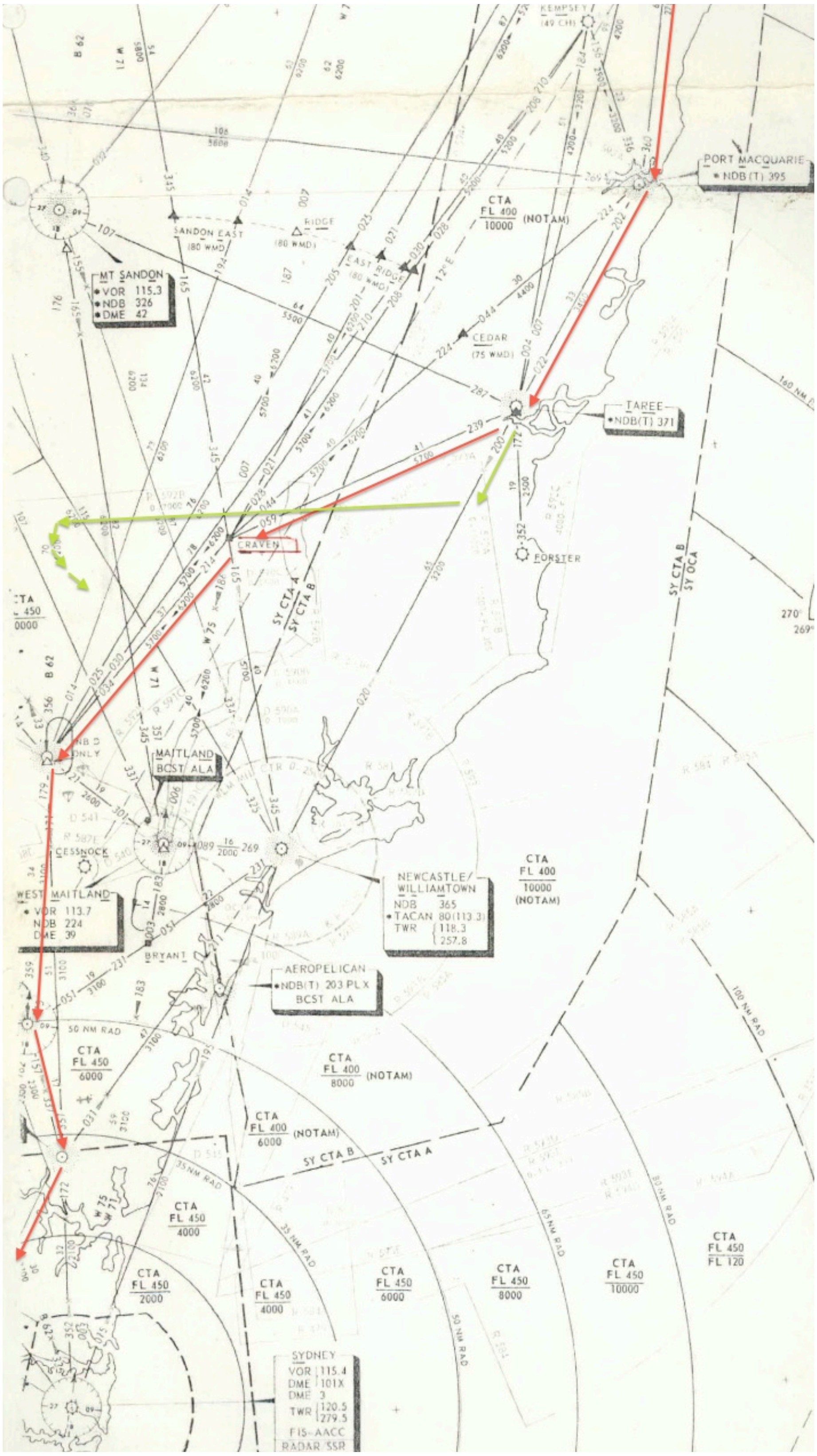

Figure 1: Planned and actual flight path of VH-MDX. Red arrows depict the planned route (paralleling the planned tracks and navaids) and green arrows depict the approximate actual track to the 320˚M/45NM Williamtown radar fix. If the pilot of VH-MDX turned towards Craven intersection when he stated to FIS-5 his intention to do so, contrary to the pilot's and ATC/FIS suggestions, VH-MDX was not particularly close to the Williamtown controlled airspace boundary (Base chart: Australian Government (Department of Transport Australia) c.1981).

2.3. Initial Sydney radar fix

VH-MDX was identified by Sydney Air Traffic Control (ATC) radar at approximately 36NM north of Singleton NDB, just west of the Singleton NDB to Mount Sandon NDB track[1] (the latter marked in red in the figure below).

This fix lies between Moonan Brook and the Polblue camping grounds[2]. This initial radar identification is depicted in figure 2 below as position '1' and was made just after 0928:28UTC. VH-MDX was identified with Secondary Surveillance Radar (SSR) SPI ident so, was *positively* identified.

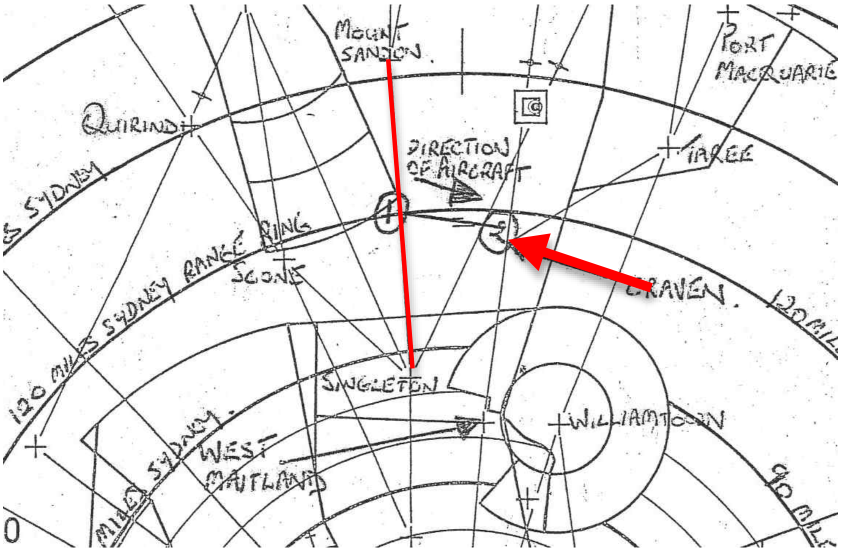

Figure 2: Sydney radar positions of VH-MDX. '1' is the initial Sydney radar position, '2' is the final observed radar position. The red line depicts the Singleton NDB-Mount Sandon NDB track. Craven intersection/waypoint is at the tip of the red arrow (Base image: Australian Government (Department of Transport Australia) 1981).

From this position VH-MDX turned approximately southbound for a short period[1][2] then was observed on Sydney ATC radar *slowly* turning to a generally easterly course[2]. Figure 1 depicts this.

To ensure continuity of radar coverage of VH-MDX, Sydney ATC sought assistance from RAAF Williamtown ATC radar that was located approximately half the distance to VH-MDX than the Sydney northern ATC radar heads were[4].

2.4. Williamtown radar fixes

Only a single, *complete*, highly reliable radar fix was made of VH-MDX by RAAF Williamtown ATC radar being at a position 320˚M/45NM from the RAAF Williamtown ATC radar head at around 0936:00UTC[4].

No further *confirmed* observations of VH-MDX were made by Williamtown ATC radar except for verification that there were no longer any radar returns from VH-MDX[4] from 0941:10UTC onwards[1].

Communication transcripts show a call stating '330_____' at 0938:30UTC. The Williamtown Air Traffic Control Officer (ATCO) does not recall making this call or *consciously* observing the radar display[4]. Despite this the Williamtown ATCO does state that if he did make the call then the bearing information would highly likely have been derived from valid radar based information[4].

It was also suggested that Sydney ATC may have made the call to update Williamtown or that indeed the Williamtown ATCO did make the call despite not remembering[4].

A conclusion was drawn that the 330 call does hint at a likely position fix but without further information narrowing of tolerance is not possible[4]. Accordingly it was suggested that this 'fix' should be considered but with caution[4].

The 330 call suggests a generally *easterly* track from the 320˚M/45NM fix, which corroborates with Sydney ATCO suggestions of the same[2].

Following the 320˚M/45NM radar fix, communication transcripts show that VH-MDX is descending, culminating in a final call from the aircraft of '*5000*' (feet altitude) at 0939:26UTC.

2.5. Final Sydney radar position

A Sydney ATCO deposed that the final observed position of VH-MDX by Sydney ATC radars was approximately 5NM west to north-west of Craven intersection/ waypoint[5][6]. This is indicated as position '2' in figure 2 and no time is given for this specific position.

Both communication transcripts of the Sydney Sector 1 ATCO[1] and ASIB/BASI reports[1] indicate radar contact was lost at 0939:00UTC so, it is quite *possible* that the 5NM west to north-west final observed Sydney radar position occurred at this time.

Specifically, communication transcripts[1] show that radar contact was implied as lost by Sydney ATC at 0939:00UTC with the following transmission from Sydney Sector 1 to Williamtown ATC: '*You got a present heading, we've lost him- to track him towards yours*'.

It should be noted that even if radar fade had occurred at Sydney around 0939:00UTC, a subsequent 'pop up' return may have occurred at a later time due to changes in the propagation path (terrain, aircraft altitude etc).

It was stated by one ATCO that only *primary* radar returns were observed during this fix although understandably given the significant time frame since the accident to the present day there was uncertainty[2]. Radar propagation analysis has shown that coverage was possible down to *at least* 6000'AMSL at this position[2].

2.6. ASIB/RCC final radar position

Bureau of Air Safety (BASI) Accident Investigation archives reveal a final position by Williamtown radar at 0940UTC in the Upper Williams River area[1].

This is approximately 10NM west of the Sydney ATC last observed radar position[4]. The position appears to have been filed around a month after the accident[4].

This position was reportedly generated by the Sydney Rescue Coordination Centre (RCC) and does not appear to be reported by either Sydney or Williamtown ATCO's[4]. The basis for this position is unknown so is of questionable defensibility[4].

There was only one ATCO at Williamtown ATC on the night of the accident and the sole Williamtown ATCO confidently states he did not observe VH-MDX radar fade[4]. These facts nullify this position as a *Williamtown radar fade* location.

Rather than a *final* radar position, this position has also been suggested to be a refined 320˚M/45NM 0936:00UTC position based on refinement and consolidation of both Sydney and Williamtown radar information at the fix time[4].

2.7. Communications

Sydney Flight Information Service (FIS) 5 using frequency 121.6MHz, was the only Air Traffic Service (ATS) agency to communicate with VH-MDX after Taree[1][3].

The ground transceiver station for FIS-5 was located on Mt Berrico[3]. FIS-5 received the final recorded transmission from VH-MDX at 0939:26UTC being '*5000*'[1].

Following acknowledgement of the '*5000*' call, FIS-5 next attempted communications with VH-MDX 1 minute and 12 seconds later[3].

QF26 was the first airborne aircraft to attempt communications with VH-MDX approximately 12 minutes after the final received call[3].

3. Radar information

3.1. Radar heads

Three radars of interest have been identified that may have contributed to positional information of VH-MDX in the final 15 minutes of flight[2][4]. These are[2][4]:

- Sydney Route Surveillance Radar (RSR) operated by Sydney ATC
- The Round Mountain RSR operated by Sydney ATC
- RAAF Williamtown SURAD (Surveillance Radar) Terminal Approach Radar (TAR) operated by Williamtown ATC

It has been found that *Sydney* RSR was *highly unlikely* to contribute to VH-MDX positions as earth curvature and terrain masking was significant between the Barrington/Gloucester Tops area as the Sydney RSR head position was located at sea level[2][4].

The Round Mountain RSR and Williamtown TAR radar heads were found to *have* been able to contribute to VH-MDX radar positions[2][4]. The Round Mountain RSR head was located upon high terrain of around 5200'AMSL allowing significant line of sight whilst the Williamtown TAR was located half the distance to VH-MDX than either of the Sydney RSR's.

3.2. Most reliable radar fix

The 320˚M/45NM radar fix obtained by Williamtown ATC at 0936:00UTC is classed as being *highly reliable* and of good accuracy and precision[4]. This is because:

- Williamtown radar was located at less than half the distance to VH-MDX than the Sydney ATC northern RSR's were[4]
- Williamtown ATC radar was configured as a TAR thus, having a sweep rate much faster than the Sydney RSR's (faster display update)[4]
- VH-MDX was positively identified by squawk ident (SPI) (triangle) and Mode A SSR symbol (likely a circle) superimposed over each other[4]
- 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[4]
- 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[4]. 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)[4]
- The maximum range can be further refined as the ATCO observed *full* and *unclipped* SSR symbology[4]; so, VH-MDX was not more than a maximum distance of approximately 47NM to preserve SSR symbol integrity[4]
- Sydney Radar passed on a position of 320˚M/46NM approximately 1.5 minutes previous that grossly aligns with the Williamtown ATCO's position[4]
- The ATCO confidently reported that VH-MDX was observed on the 320˚ bearing and that he would have said 318˚ or 322˚ if such a bearing was observed[4].
- An individual who talked to the Williamtown ATCO within weeks of the accident stated +4˚/-0˚ was suggested.

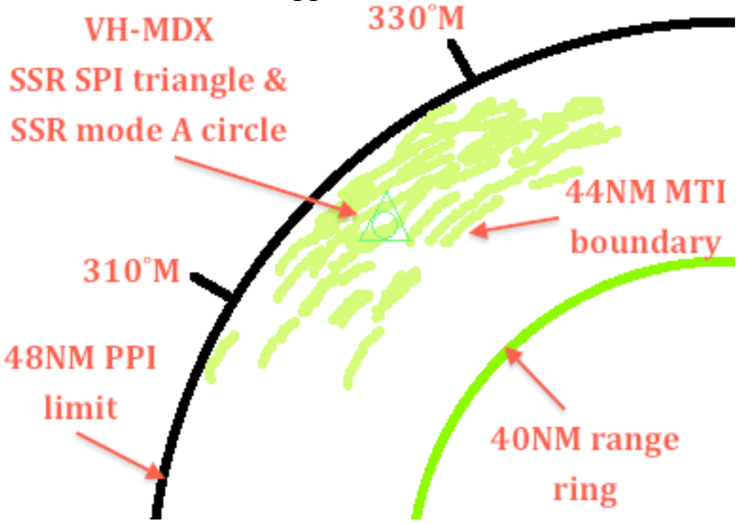

Figure 3: Reported position of the 320˚M/45NM fix. Despite the permanent terrain clutter, the SSR symbology of the returns were readily apparent to the Williamtown ATCO because of shape. Bearing read-off was simple given the proximity of the returns to the compass rose on the outer edge. The compass 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. Overall, this radar fix is the most defensible accurate and precise available (Image: Strkalj 2014).

Considering the points above and in section 2, the 320˚M/45NM Williamtown ATC radar fix is clearly the most reliable, accurate and precise *latest* radar position of VH-MDX available.

<u>The 320˚M/45NM Williamtown Radar fix at 0936:00UTC will be used as a starting point for a Maximum Possible Extent analysis</u>

3.3. Radar tolerances: 320˚M/45NM fix

It was described how the following tolerances are applicable to SURAD operations involving the Tower radar display (PPI) (used during the VH-MDX accident)[4]:

- +/-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

In the case of the 320˚M/45NM fix, it has been shown how the ATCO suggested in 2014 a +/-2˚ tolerance[4]. This was backed by the reported ease of bearing/range assessment due to return proximity to the compass rose and also when returns were referenced to permanent terrain clutter[4]. Accordingly, a tolerance of +/-2˚ was accepted for this fix[4].

Despite this, there is information suggesting a +4˚/-0˚ tolerance may have been more indicative of the 320˚/45NM fix[4]. There is uncertainty as to the accuracy of this claim but given the nature of the statement it is viewed likely. It must be remembered over thirty years has passed since the accident and memories are being tested.

Section 2.6 discussed how the ASIB/RCC final radar position could be a refined and consolidated 320˚M/45NM 0936:00UTC position. When plotted, this position is located at 325.9˚M/46.7NM from Williamtown SURAD[4] yielding a deviation of +5.9˚/+1.7NM from the 350˚M/45NM position.

Despite these findings, to allow for the possibility of maximum expected error, assumption of a quick visual assessment tolerance of +/-10˚ should be considered in a *Maximum Possible Extent* type analysis.

Range tolerance was determined to be +2NM/-0NM based on ATCO interviews and cross checking VH-MDX returns with permanent terrain clutter. As VH-MDX returns were within permanent terrain clutter (i.e. outside 44NM) and inside 48NM (scope outer edge) allowing for this position between these two ranges is conservative.

Accordingly, the range band of 44NM-48NM representing the *definite* area VH-MDX was in should also be considered in such an analysis.

<u>For a Maximum Possible Extent analysis, +/-10˚ bearing and + 3NM/ -1NM range tolerances reflecting the *maximum* tolerances likely will be used.</u>

4. Aircraft performance

4.1. Average altitude

VH-MDX was operating approximately between 7500'AMSL to 8500'AMSL from the initial Sydney radar fix to around the 320˚M/45NM Williamtown radar fix. From here over a space of 3.5 minutes, VH-MDX eventually *reported* being at 5000'AMSL with a gradually increasing descent rate.

As the period of interest is from the 320˚M/45NM fix, an altitude of 7000'AMSL represents the final minutes of flight well when calculating True Air Speed (TAS) and considering winds.

4.2. Relevant 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].

It cannot be confidently concluded exactly what profile was apparent during the descent phase or even when descent commenced. Descent may have been the result of:

- Failed attempt at a climb due to icing and/or turbulence using normal or best performance climb speeds (slow speed)
- Loss of control during a normal cruise profile as a result of insufficient primary flight instrumentation, turbulence and icing (high speed).

The latter is a highly possible although, often disregarded possibility. 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[17]. Indeed the pilot's intention was to: '*.... try to continue our flight plan*'[1].

The most critical scenario to the maximum extent 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 an entirely possible situation and may have eventuated because of failed primary attitude instrumentation leading to:

- 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 climb-powered descent will result in maximum displacement from the 320˚M/45NM fix within the scenario, accordingly, such a profile must be used for Maximum Possible Extent analysis.

C-210 engine power is set by adjusting Manifold Pressure (MP) with the throttle and propeller RPM with a propeller pitch control lever. Standard *climb* power for the C-210 is full throttle to a maximum MP of 25" and 2550 RPM[8].

At 7000'ISA only around 23" of MP is possible so, setting full throttle and 2550RPM at this altitude yields engine output power to establish a ≈75% cruise power setting[8]. 172KTAS would be theoretically achieved in *level* flight[8].

As the situation became desperate, the pilot of VH-MDX would likely have extracted maximum or close to maximum power output of the engine. 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*[8]
- Takeoff Power setting of 2850RPM which is rated for only 5 minutes[8].

There are no KTAS figures available for either level or descending flight with either MCP or takeoff power set[8] as these are not normal cruise or descent power settings. As a result, some allowance must be made to the ≈75% cruise TAS to account for MCP or takeoff power being set whilst descending.

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

- The average 7000' altitude used significantly minimises power gained though advancement of the propeller RPM
- 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 172KTAS would be realised at 75% power setting at 7000' ISA).
- 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.

<u>A TAS of 192 knots will be used for Maximum Possible Extent analysis.</u>

5. Tracking assumptions

5.1. Direction from 320˚M/45NM

VH-MDX was found to have likely tracked in a generally *easterly* direction following the 320˚M/45NM fix[2][4]. Despite this, both Sydney and Williamtown ATCO's are not *completely* confident of this whilst radar propagation analysis so far has revealed low probability of detection at the final Sydney radar fix at 5000'AMSL[2][4].

It must be remembered that it is *not* the objective of this paper to suggest specific small areas of interest based predominately on *assumptions*. The objective is to define *conservatively* derived boundaries of interest to minimise over-filtering. Accordingly, tracks in all directions (360˚) from the 320˚M/45NM fix will be accounted for.

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. Accordingly, VH-MDX may have impacted anywhere from the 320˚M/45NM fix to the maximum distance possible in a straight course at specified speeds and time intervals.

When considering the Maximum Possible Extent analysis, no specific tracking direction from the 320˚M/45NM fix should be considered rather, *all directions* from this fix should be used (360˚).

5.2. VH-MDX altitudes

From BASI communication transcripts[1], the following altitudes (AMSL) for the specified times are found based on *pilot calls*:

- 8000'-8500' 0929:11UTC '*MDX I'm struggling to get 85*'
- 7500' at 0937:40UTC
- 6500' at 0938:29UTC
- 5000' at 0939:26UTC

From this, the following *assumptions* are made of VH-MDX's altitude:

- Between at least 7500' and 8000'AMSL for 1 minute and 40 seconds from 0936:00UTC
- At an average of 7000'AMSL for 49 seconds from 0937:40UTC
- At an average of 5800'AMSL for 57 seconds from 0938:29UTC

It must be considered in a general sense that pilot calls of the indicated altitude may be delayed or pre-empted. Additionally, *actual* altitude may have been lower given altimeter hysteresis, cold temperature or delay in making the calls however, these areas will not be accounted for.

As stated in section 4.1, 7000'AMSL will be used as a mean altitude representing the final few minutes of flight from the 320˚M/45NM onwards.

5.3. Timings

There has been no method found so far to verify timings of ATS recordings. Nolan in *Operation Wittenoom VH-MDX Research*[11] does present a reasonable case suggesting the timings of recordings should be taken as accurate.

Chessor[17] on the other hand exposes the problems associated with using compact cassette versions of audio recordings in determining timings of calls highlighting the timing variability possible.

As there are no recordings available on the original medium used, nor are there *quality* and verifiable compact cassette recordings of the audio available to the author, a critical assessment of timing cannot be carried out.

It is assumed the Department of Transport (DoT) reported timings in *transcripts* are correct based on the expectation that appropriate standards, procedures and equipment were in place to ensure accuracy of recording timings

The final call by VH-MDX was made at 0939:26UTC, approximately 3.5 minutes after the 320˚M/45NM fix[1].

The Williamtown ATCO consciously observed the PPI at 0941:20UTC, approximately 5.5 minutes after the 320˚M/45NM fix and found no radar returns from VH-MDX[1][4]. The first communications attempt of FIS-5 with VH-MDX following the 5000' call acknowledgement was at 0940:38UTC, approximately 4.5 minutes after the 320˚M/45NM fix[1][3].

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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 impact time on no-communications or radar fade is *not* a completely defensible approach.

Considering the ever increasing final rates of descent (almost 2000fpm)[1] and terrain 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, thus impacting terrain. 2.5 minutes at 2000fpm after the final call would result in VH-MDX being at Sea Level if the descent rate trend continued.

Accordingly, a time interval of 2.5minutes after the final '5000' call will be considered. This equates to approximately 6 minutes after the 320˚M/45NM fix. Such a time also covers the 5.5 minutes to no radar returns observed and 4.5 minutes to no communications response.

<u>A maximum fly on time of 6 minutes from the 320˚M/45NM fix will be considered.</u>

6. Environmental conditions

6.1. International Standard Atmosphere (ISA) deviation

The closest altitude to 7000'AMSL from the ARFOR indicting a temperature forecast is 10 000' AMSL being -9ºC thus indicating ISA-4 conditions[1].

A report from the pilot of VH-AZC tracking coastal from Taree to Williamtown and south, reported an Outside Air Temperature (OAT) of -2ºC at 8000' AMSL indicating ISA-1 conditions[1].

Colder than ISA conditions yield slower TAS values for the *same* Indicated Air Speed (IAS) flown by the pilot but increased engine power is generally available which may actually increase TAS.

In spite of this, the differences between ISA and ISA-4 are subtle. Additionally, the actual conditions during the night of the accident appear only slightly colder than ISA in any case.

<u>Accordingly, for the *Maximum Possible Extent* analysis ISA conditions will be used.</u>

6.2. Mountain wind effects

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.

6.3. Wind

Given the *assumed* altitude flown by VH-MDX as described in the previous sections, use of the 7000' Area Forecast (ARFOR) wind of 250ºT/40[1] knots throughout the leg from 0936:00UTC to impact with terrain can be justified.

The wind was also reported as 'westerly' with speeds up to 70 knots stated by some pilots airborne that night[1]. As a result, 70knots should also be considered to account for a maximum *reported* wind velocity.

Variation in direction should also be accounted for and a south-westerly to westerly sector should be assumed. Such a sector is assumed as airport Terminal Area Forecasts (TAF's) in a broad area around the Barrington Tops[1][10] coupled with prognosis/synoptic charts[9] show forecast winds on the night and the following day were mainly south-westerly with some southern airports westerly[10].

<u>Wind directions of 225˚T-270˚T and wind speeds of 30kt-80kt (forecast and reported winds +/-10 knot buffer) will be used for a Maximum Possible Extent analysis.</u>

7. Parameters for analysis

The following parameters are derived from the previous sections and will be used in the Maximum Possible Extent of flight analysis.

Condition	Value
RAAF Williamtown SURAD Radar Head Position (WGS84)	32°48'1.30"S,151°49'40.06"E UTM: 56H 3 90248.29, 6370236.35
320˚M/45NM Radar Fix Bearing Tolerance	+/-10˚
320˚M/45NM Radar Fix Range Tolerance	+3NM/-1NM
Temperature Deviation	ISA
Aircraft Speed	192KTAS
Tracking Assumption from 320˚M/45NM Radar Fix	All directions (360˚)
Maximum Flying Time Interval from 320˚M/45NM Radar Fix	6.0 Minutes
Wind Direction	225˚T-270˚T
Wind Speed	30kt-80kt
Turn Rate	Straight Courses From 320˚M/45NM

Figure 4: Maximum Possible Extent of flight analysis parameters. These parameters are *highly conservative* accounting for much larger deviations than have been confirmed or were likely. The result of such an approach will be to ensure full capture of all possible geographical areas VH-MDX may have impacted. Further specific analysis will be carried out in future papers to define smaller areas of interest to guide search operations.

8. Results

8.1. Overview

Figure 5 below depicts the results from simple flight modeling based on the parameters defined in previous sections. It is almost certain that VH-MDX is within this area, and almost impossible for it to be outside of it. Annex A contains a larger version of the map.

The map was drawn in Google Earth[12], using the Nokia Road Maps overlay[13], with a UTM grid overlay[14].

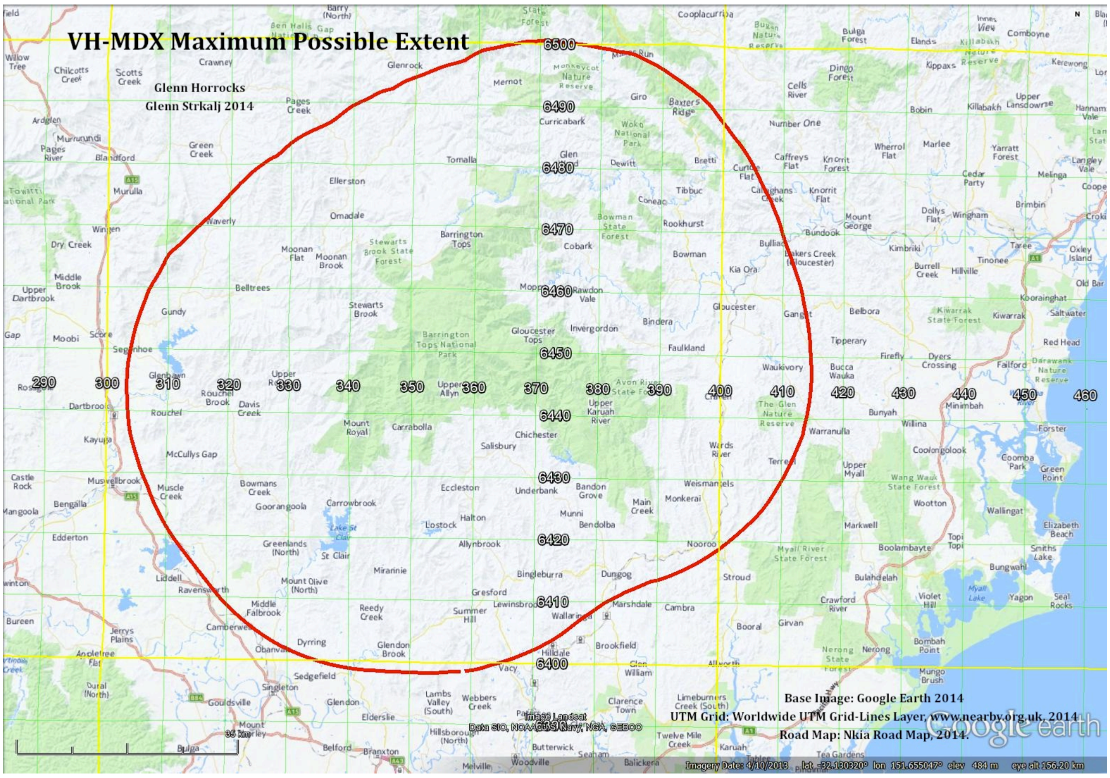

Figure 5: VH-MDX Maximum Possible Extent of flight. VH-MDX is highly likely to be resting *within* the red boundary. For all practical purposes, there should be no consideration of impact areas outside of this red boundary.

9. Conclusion

A *highly conservative* Maximum Possible Extent of flight analysis was carried out. A useful map was synthesised depicting a Maximum Possible Extent boundary based on a high-powered descent and *broad* tolerances.

This analysis provides a conservative coarse filter for emergency services and researchers to confidently restrict *detailed* intelligence and search activities within the defined area.

10. Recommendation

Information which suggests that VH-MDX could be *outside* the area depicted in figure 5 should be regarded as *extremely unlikely*.

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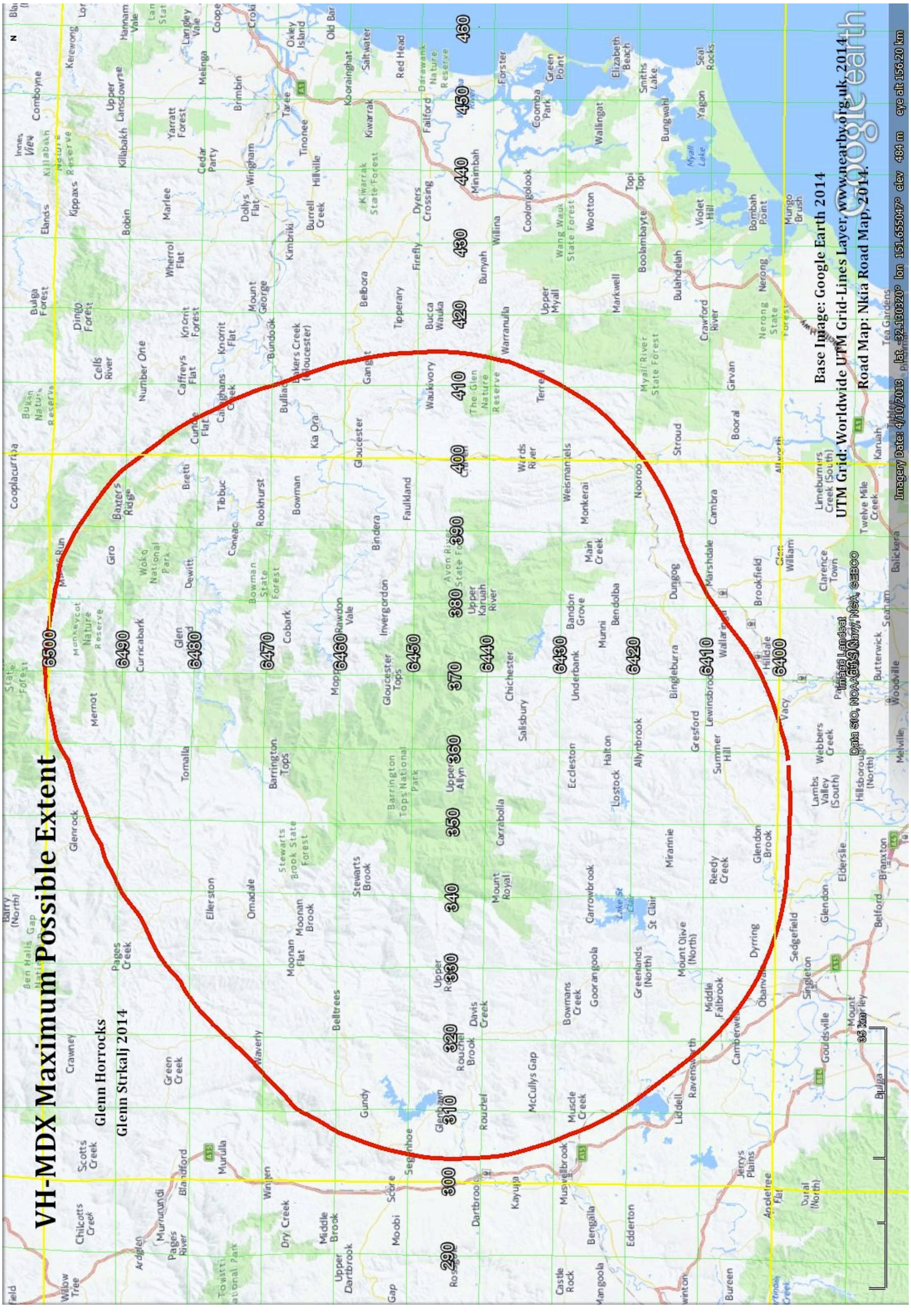
[17] Chessor. D, 1990, *Research into Probable Crash Sites in Barrington Tops of Cessna 210 VH-MDX*, Sunday 19:40 HRS, 9th August 1981, Draft, 25th September 1990.

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



Annex B: Details of modeling approach

The approach used to convert the scenario into a Maximum Possible Extent is as follows:

1. A spread of values is taken from the lowest to highest value of each parameter.
2. A large array of every possible permutation of those parameters is generated.
3. The location which every permutation results in is calculated assuming *straight* flight. This will generate a cloud of geographic points. We now need to find the outside edge of this cloud of points.
4. The centroid of the cloud is calculated.
5. For every 1° of arc around the centroid the distance to all permutation points in that arc is calculated. The point at the greatest distance is stored.
6. The 360 greatest distance points then describe the maximum limit of the locations resulting from the scenario.

This was programmed into a python program[16] and calculated using the array functions in the numpy numerical module, and the simplekml module was used to generate a Google Earth output file for display. We will now describe each of these steps in more detail.

1. Spread of Values

The following values were used:

Parameter	Values	Variable	Description
Position of Williamtown SURAD	390248E, 6370236N	T_E , T_N	UTM location, on WGS84. Actual position positively confirmed.
Magnetic Deviation	11.43°E	*MagDev*	Source[15]. Known to be accurate
Radar fix radial (°M)	[310, 315, 320, 325, 330]	*FixBearing*	320° +/-10° in 5° increments
Radar fix range (NM)	[44, 45, 46, 47, 48]	*FixRange*	45, +3/-1 in 1NM increments
TAS (knots)	192	*TAS*	Only considering maximum possible airspeed
Aircraft Tracks	0-360° in 1° increments	*AircraftTrack*	All straight tracks
Flying Time after 320/45 fix (seconds)	360	*FlyTime*	Only considering maximum possible flight time
Wind Direction (°T)	[225, 230, 235, 240, 245, 250, 255, 260, 265, 270]	*WindBearing*	255°-270° in 5° increments
Wind Speed (knots)	[30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80]	*WindSpeed*	30-80 knots in 5 knot increments

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2. Generate Large Array

The scenarios listed are then used to generate a large array which contains all permutations of these scenarios. This results in 5×5×360×10×11=990000 permutations.

3. Calculation of Scenario Points

The calculations are done on a UTM grid for simplicity. These calculations are done using the array functions in numpy to process the large dataset quickly.

First an array of the permutations of the Williamtown radar fix are calculated:

$$Radar_E = T_E + FixRange \times \sin(FixBearing + MagDev)$$
$$Radar_N = T_N + FixRange \times \cos(FixBearing + MagDev)$$

Now the vector addition of the aircraft speed and wind speed are calculated:

$$E = Radar_E + FlyTime \times \left(TAS * \sin(AircraftTrack) - WindSpeed * \sin(WindDirection)\right)$$
$$N = Radar_N + FlyTime \times \left(TAS * \cos(AircraftTrack) - WindSpeed * \cos(WindDirection)\right)$$

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