Sastrugi and its effect on Ground Penetrating Radar

The area where the search was carried out was subject to extensive sastrugi (wind-blown frozen 'waves'). It was clear from the first search that the radar unit was forced to rock back and forth when traversing the sastrugi, so it was decided to flatten them out as much as possible before the second search to eliminate any possible error.

Accordingly a large area encompassing the proposed new searches was flattened using a device built with the help of Ben Burdett, Carpenter. This was remarkably effective, and soon provided a relatively smooth, gently undulating surface.

Figure 18 sastrugi disturbed the stability of the radar aerial (Photo: David London)

Figure 19:*clearing sastrugi with a custom made cutting implement (Photo: David London)*

Figure 20 ***: smoothed sastrugi gives clear surface for second radar scan. Ben Burdett (front) and Chris Henderson (rear) demonstrate different opinions on how hard it is to pull the cart. (Photo:David London).***

THE SECOND SEARCH USING GROUND PENETRATING RADAR

This section of the report deals with the second, more detailed search for the frame. Results from this scan were used to determine where to dig a trench. As it turned out what we found was an ice layer, not a frame. But what we also found was a probable channel in the rocks where the frame could be today.

GPR scan shows reflections consistent with the airframe

The raw data from the GPR equipment gives a 2D representation of objects below the surface. In effect it is rather like an echo sounder in a boat, except echoes are visible all the way down whereas an echo sounder only shows the bottom (and perhaps some fish).

The second scan consisted of two overlapping 17m circles, which covered a large area in the vicinity of the estimated place of the air tractor. The overlap was where the air tractor could be. The next figure shows the GPR output after it had been filtered to reduce extraneous data such as the ground echoes, and enhance deeper radar reflections which have a tendency to fade out.

The features of this scan are the two bands at 1-1.5m and 2-2.5m. Within these bands can be seen recurring ‘bumps’. The repetitive nature of the echo is a feature of the spiral scan, since obviously every time it goes around again the radar unit will pick up the same feature. In order to put this together in a contour map, the trace at 2-2.5m was averaged and the result plotted as a 2D map of the strength of the signal. What this does is, in effect, give a contour map rather like a topographical map, of the radar reflections.

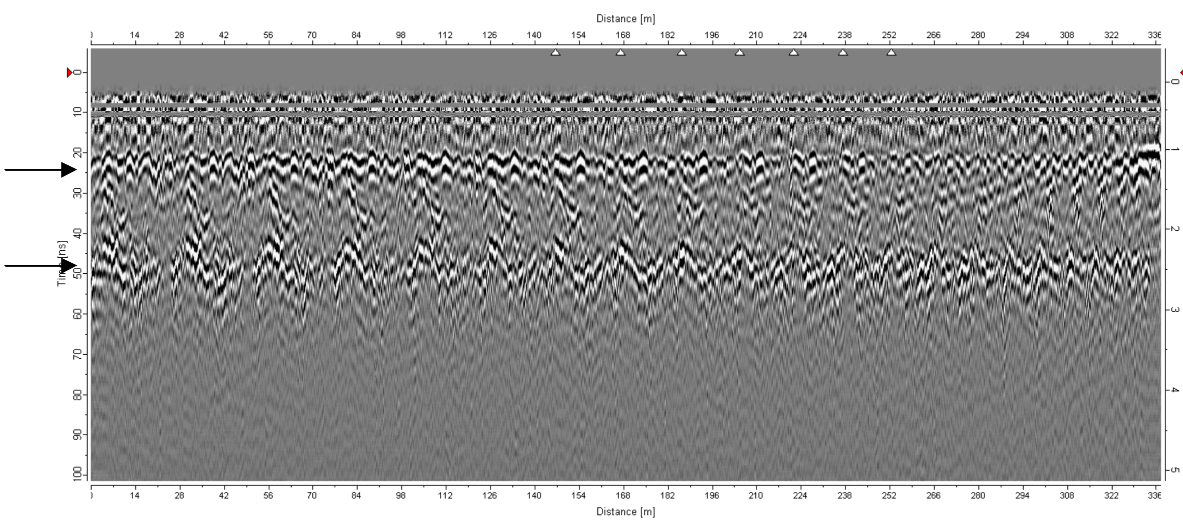


Figure 21: ***Processed GPR data showing two bands of significant radar echoes. The deeper one corresponds to the level the plane could be at, and showed features consistent with an elongated frame on the contour maps (see below).***

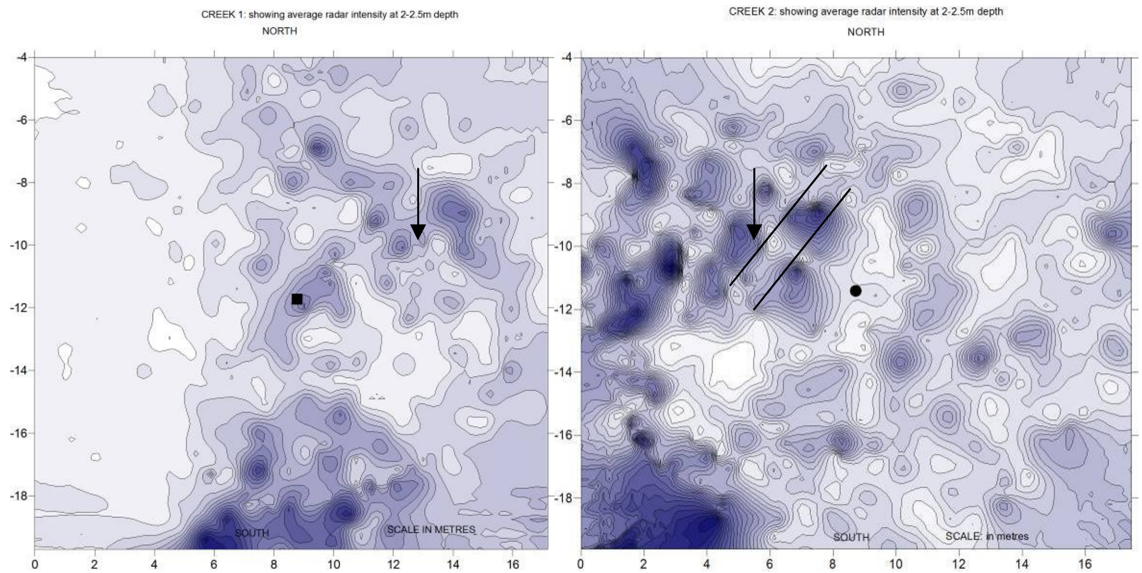


Figure 22:
Contour maps of two overlapping 17m scans provide a picture of the radar reflections at about 2.5m depth in the ice over a large area of about 25 m x 17 m. The point in the centre is the pole around which the rope winds in a spiral. The spot where the transects crossed (indicating the Air Tractors' position) is shown by vertical arrows. A 3mx 2.7m trench was dug at right angles to the main area of interest (shown approximately by the slanting lines).

Digging the trench

Having established the estimated position for the air tractor, and got what looked like a significant echo of about the right size, an exploratory trench was dug down to the level of interest.

Figure 23: start of second dig. The coats hang on the post at the centre of the circular search area. The small orange tag in front of the chainsaw (arrow) is the spot where the three transit lines cross and represents the position where the air tractor frame was until its last sighting in 1976. (Photo:David London)

Figure 24*: end of the dig. The dig was stopped below sea level. These pictures give an idea of the final size of the hole. (Photo:David London)*

Digging was done using an electric chainsaw (lubricated with vegetable oil), and a shovel and crowbar to lever out blocks of ice. (Chainsaws blades can be made for faster ice digging by filing off half the kickback tangs[6]). The dig took about 8 hours spread over two days. At about 1.25 m a layer of hard ice was encountered consistent with the melt of 2002, and shown on the radar scan ().

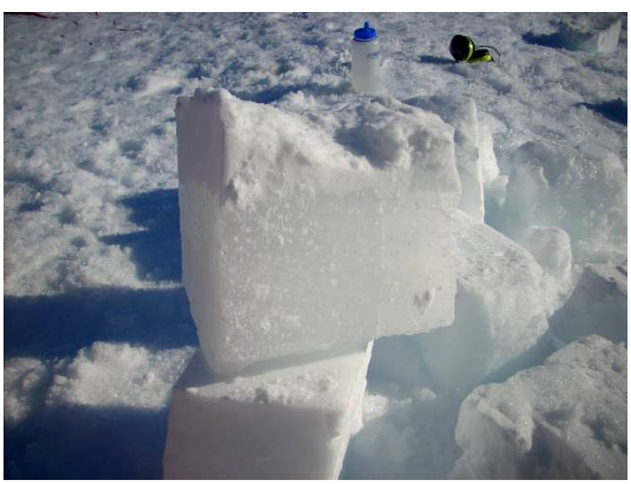


Figure 25
Layer of clear hard ice encountered at about 1.25m which is shown on the radar scan (Figure 22:) and at a depth consistent with the ice level estimated from pictures of the 2002 melt.

[6] http://www.icesculptingtools.com/modify_a_chain.htm

Hard ice with seaweed found at the bottom of the trench implies a big melt

Near the end of the dig, at about 2.5m, another thick layer of hard ice was encountered. This layer continued down until the hole was abandoned at 2.7m when it was decided that the dig had gone below the layer at which the echo was seen. It was then thought that the echo represented variations in the ice layer which happened to look the right size and shape for the airframe.

It was significant that at this level the ice contained small fragments of faeces and bits of seaweed. The faeces could have been washed down from the southern hill, but the seaweed could only have come from the sea.

A surveyors level was available, and the bottom of the hole was surveyed with reference to the benchmark AUS2030 which is at high tide level. The bottom of the hole was found to be at high tide level.

Figure 26*: At the bottom of the trench a hard ice layer was encountered at about 2.5m (arrow). This layer contained seaweed and faeces and is at high tide level. The bottom of the hole shown above is at about 2.7m and consists of hard, greenish ice. The dig was stopped at this point as it was below the area of interest shown in the contour maps. (A metal detector, capable of penetrating a further 200mm showed no activity.)*

This finding implies that, at some time in the past, a big melt had occurred, effectively removing the ice which contained the air tractor. The additional finding of a possible channel in the rocks is important, and is discussed next.

Sea surface at the edge of the scan

The large blank area filling the left third of the left hand contour map (Figure 22:) is interesting. The level of the contour map is at high tide level (established by surveying to the bottom of the trench), and hard ice with seaweed was found at this level consistent with the presence of seawater. Thus it is likely that the blank area represents smooth ice on the frozen sea surface.

The left hand edge of the contour map is hard up against the band of rock at the edge of the search area. If the area on the contour map represents the sea surface, then it suggests that the rocks go steeply down into the sea at this point. A photograph of these rocks taken during the melt in 2001 confirm that this is the case.

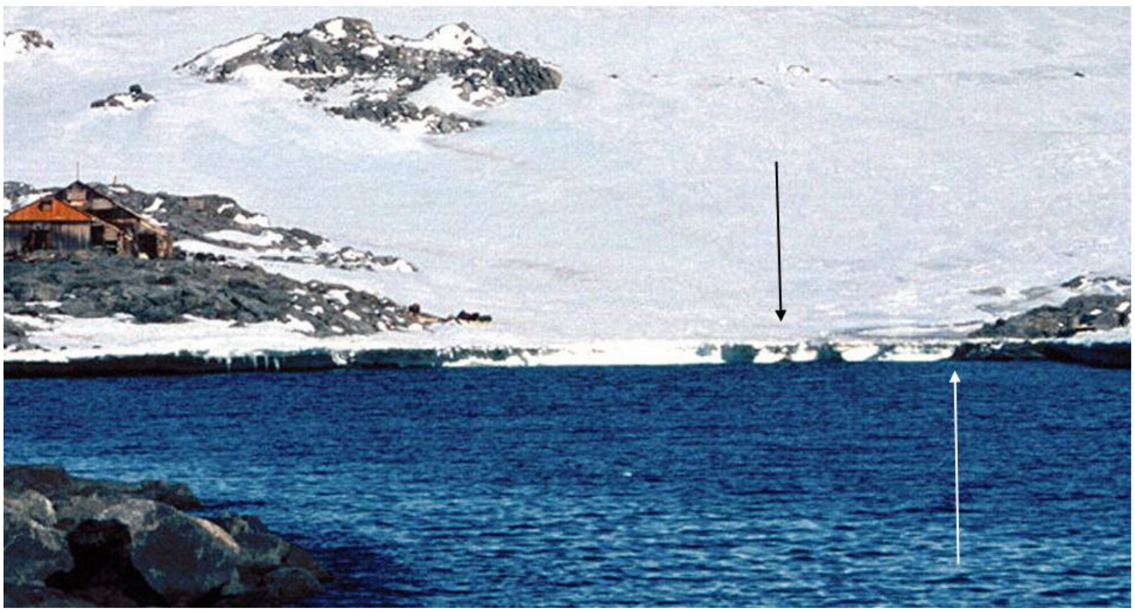


Figure 27
The area of the search from the north looking across Boat Harbour. The white arrow shows the steep sides of the rock band which is consistent with the contour map in Figure 17, and suggests that the harbour dips down into a channel at this point. **(Photo:Ian Godfrey)**

Note also the melt creek entering the harbour at the same point. The estimated air tractor position is shown by the black arrow.

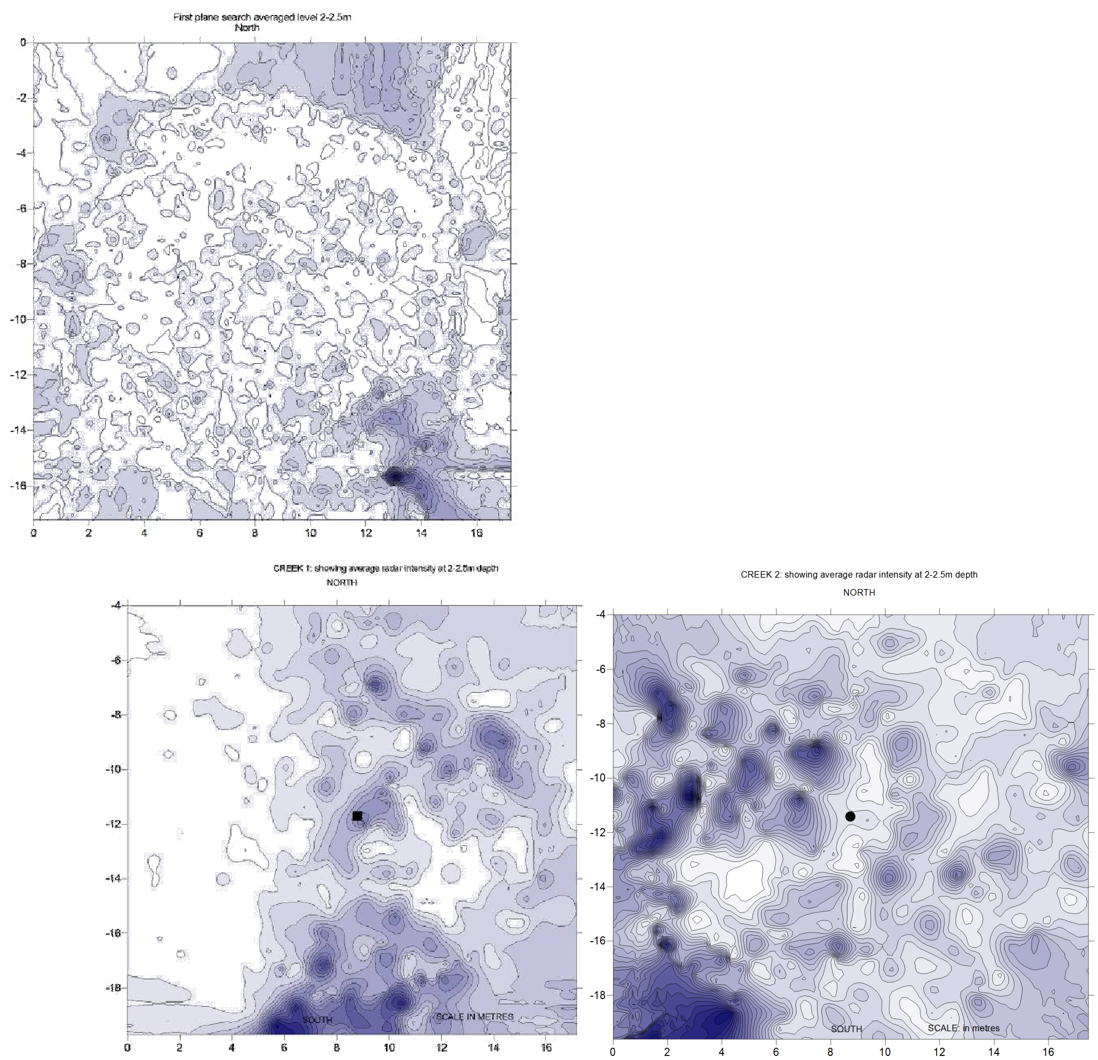
Putting the scans from the first and second searches together an hypothesis can be made regarding the topography of the harbour in this area. It seems likely that the air tractor frame was lying near a channel in the harbour which was close to its likely position should the ice melt down to the rocks. The significance of this is discussed later.

The scans from the first and second search are shown below in their approximate relationships. The interesting finding is that smooth ice seems to extend along the left hand border at a level which is known to be at high tide level.

Figure 28: this page shows the three scans, which are averaged radar intensity data at 2-2.25m depth. They are in approximately correct relationship to each other, but not overlapping. The top scan is from the 500Mhz aerial, so will show more detail than the two lower ones. The circular area in the center of the upper scan is the actual scanned area.

Significantly at the 2.5m depth there appears to be a smooth ice surface extending to the left and northwards, and a rough ice surface to the right and southwards. This, when overlaid on the other two scans, is consistent with a trench in the rocks covered with smooth ice. Rough ice is assumed to cover rocks to the right.

This is consistent with the shape of the rocks and ice seen in Figure 27.



The likelihood of a significant melt causing liquid water at the depth of the trench floor

This section is concerned with temperature data from Cape Denison and Dumont D'Urville in order to see if there is any evidence that temperatures were high enough to melt the ice surrounding the frame. It is known that a melt occurred in 2002, and it was assumed that the ice layer at found at 1.5m corresponds to this melt. Did a far bigger melt release the air frame from the ice?

Evidence was therefore sought from temperature records in East Antarctica, and specifically at Dumont D'Urville.

Temperatures before 1911

It is known that surface air temperatures over Antarctica have been rising during the past century, which has been attributed to global warming. The mean temperature increase is shown below[7]. Extrapolation backwards in time suggests temperatures were lower before 1960.

However, note that this finding refers to the entire continent of Antarctica, whereas the important temperature is the surface temperature at sea-level at Cape Denison, where no records exist except those from expeditioners and the installation of the Automatic Weather Station by the University of Wisconsin. Temperatures from 1970's and 1980's must largely be inferred from proxy records.

The following figure, taken from data about Antarctica as a whole, shows the gradual increase in temperature during the latter half of the last century. In reality it is not this simple however, because it is known that temperatures in parts of E Antarctica have been cooling since the late '70s and early '80s because of the development of the ozone hole (whereas they have been rising in W Antarctica)[8].

[7] Jones PD and Reid PA "A databank of Antarctic Surface temperature and pressure data" Climatic Research Unit, Univerisity of East Anglia, November 1999.

[8] Steig EJ et al "Warming of the Antarctic ice sheet surface since the 1957 International Geophysical Year" Nature 457, 459-462, 22 Jan 2009.

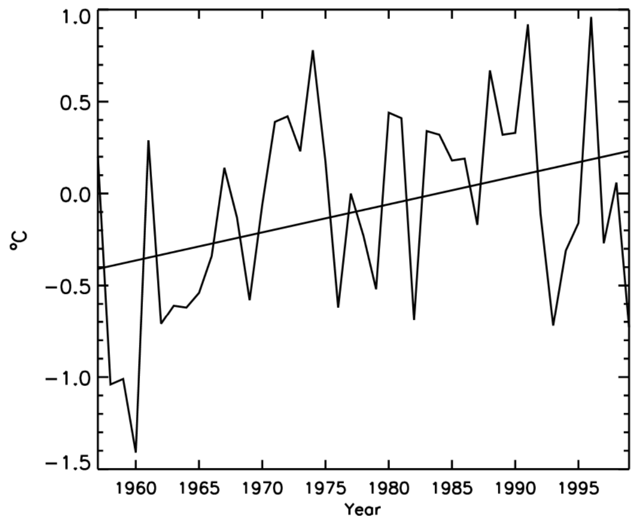


Figure 2: Time series of annual mean surface air temperature over Antarctica calculated as anomalies with respect to 1961-90.

Figure 29***: Estimate of the rise in temperature over Antarctica during the last half of 20th Century.***

Temperatures after 1976

In order to find out what the surface temperature at Cape Denison is likely to have been in the past 30 years, it was necessary to use data from Dumont D'Urville station, where records are available since the 1960s[9]. Temperatures over Antarctica tend to be recorded in different ways, mostly related to inland surface temperatures or vertical temperatures in the air column. Few records exist of sea-level temperatures, and the only data available is from Dumont D'Urville in the region of Cape Denison (see ref 2).

Temperature records from Dumont D'Urville are patchy up till about 1960, a continuous record is available from then onwards. This shows a marked increase into the 70's, and a slight falling into the '90s (*Figure 25).*

[9] http://cdiac.ornl.gov/ftp/ndp032/

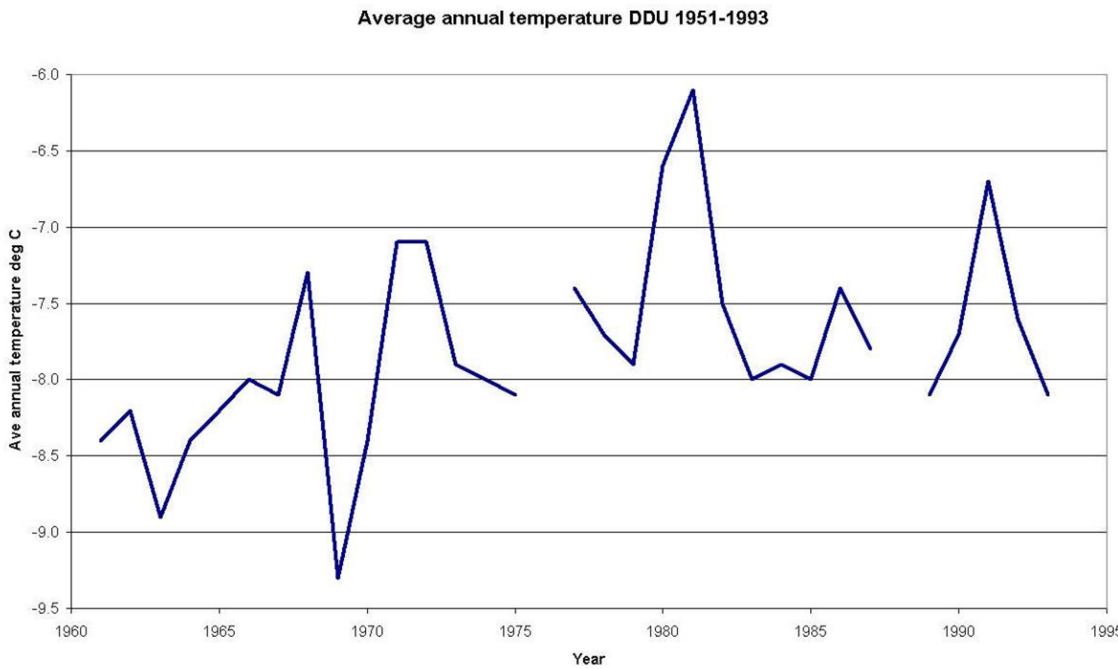


Figure 30: Average annual temperatures at Dumont D'Urville (ref 2 above) show that 1980 was a particularly warm year.

More important for melting of the ice is the maximum temperature found during the summer months of December and January. Records are available for those months from DDU 1955 – 1995, and this is shown in the next figure.

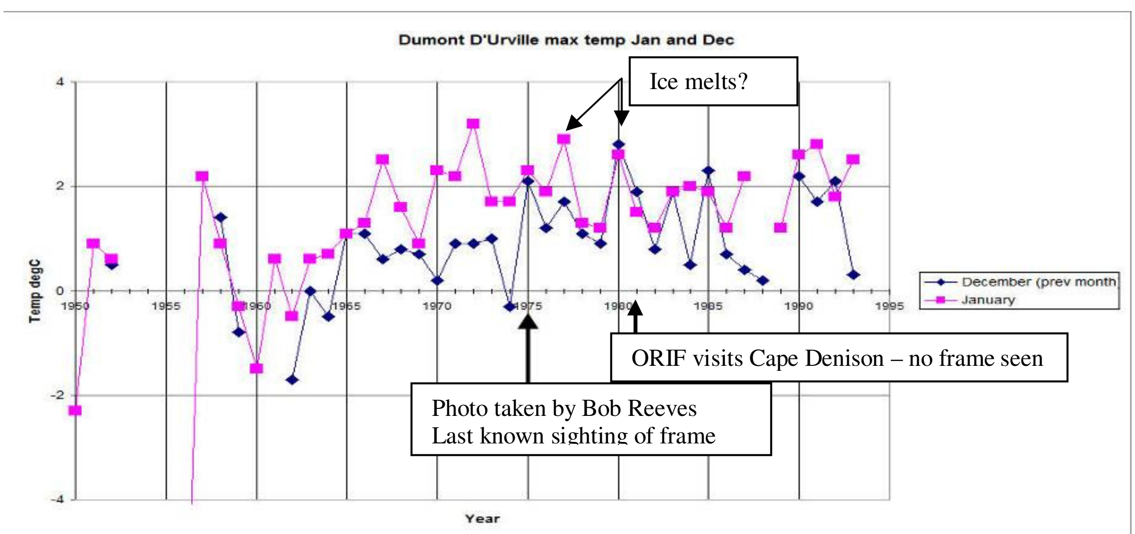


Figure 31*: **Maximum temperature in mid-summer for the two consecutive months of December and January at Dumont D'Urville 1955-1995. Note the temperatures are above freezing on a sustained basis from the early '70s. The visit by Reeves, showing the last known position of the air tractor, was in 1976 (arrow). Five years later, in 1981, the Dr Lewis ORIF expedition finds no air tractor. 1977 and 1980 have about 7 weeks of temperatures around zero at DDU, which means well above zero at Cape Denison.***

The next consideration is how Cape Denison temperatures differ from Dumont D'Urville temperatures. Dumont D'Urville is situated next to the Astolabe glacier, so will be expected to have somewhat colder temperatures than Cape Denison. There are two sets of data which show that this is the case. Records taken by Dr Ian Godfrey from this year[10] were compared with daily temperature records from Dumont D'Urville[11]

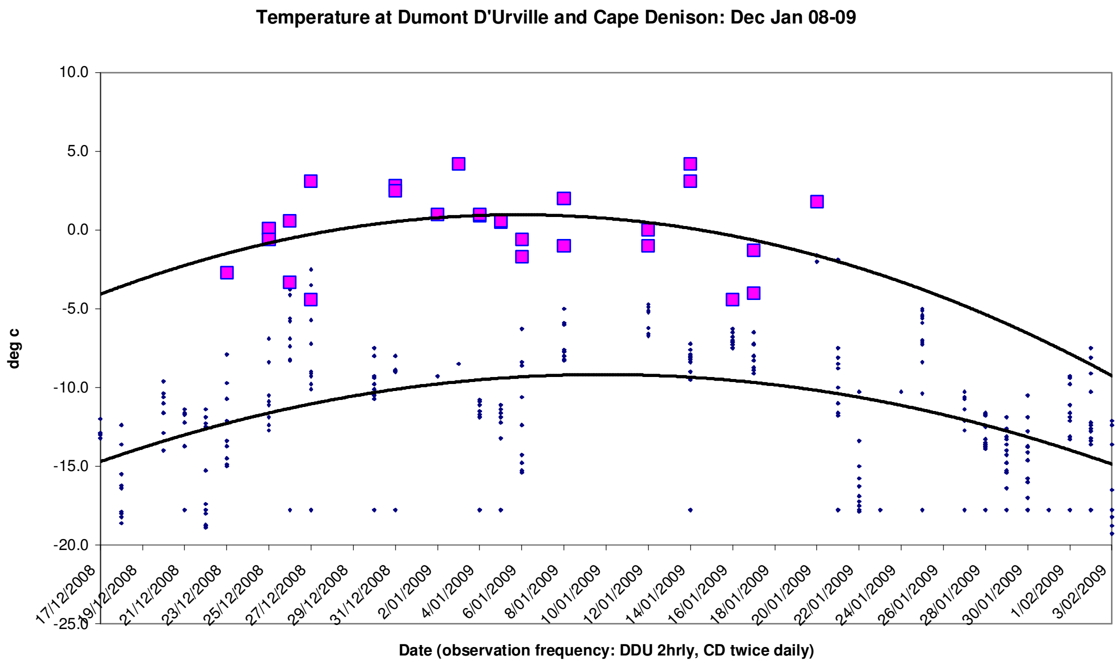
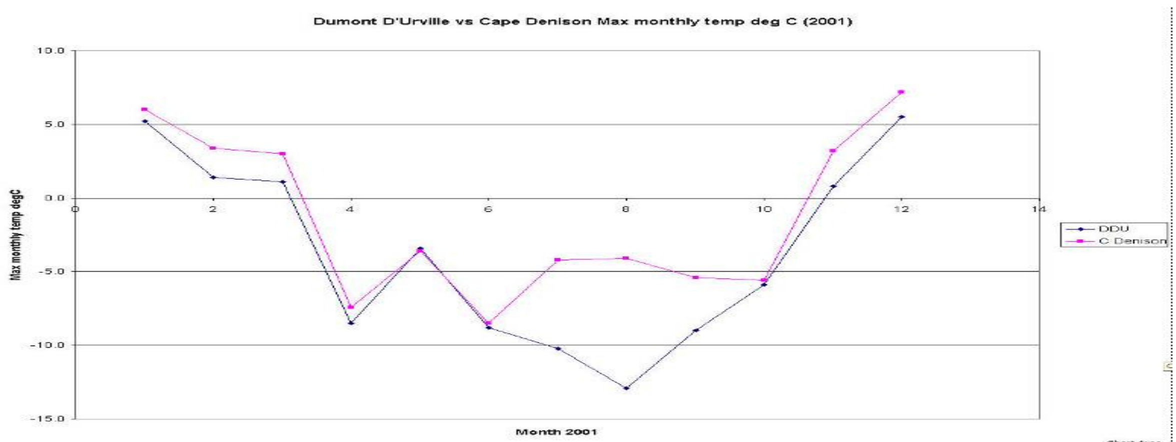


Figure 32:(above and below): Comparison of temperature records from Cape Denison (squares) with Dumont D'Urville (dots) shows that Cape Denison was up to 10 degC higher than Dumont D'Urville. This is to be expected since DDU is on a glacier. A polynomial trendline has been fitted to both sets of data.

[10] http://www.mawsons-huts.org.au/cms/conservation-expeditions/blog/

[11] DDU daily records from; http://weather.gladstonefamily.net/site/89642?tile=10;days=91#Data

Similar records for the whole year of 2001 from the AWS are shown below. The implication is that long term summer temperatures at Cape Denison are also higher, and in particular that temperatures in the late '70s could have caused a big melt.



These data are consistent with the hypothesis that maximum temperatures at Cape Denison in the late '70s and early '80s were high enough to cause significant melting of the ice at some time during that period. It does not take long for temperatures above zero to start the ice melting, and in a couple days with temperatures around 5 deg the ice level sinks noticeably. A month or two may be sufficient to cause the air tractor to be released from the enclosing ice and be exposed to the wind and to gravity.

Temperature records from Dumont D'Urville suggest when the ice melted

Figure 33 (below) shows plots of the mean daily summer temperatures (1 October – 31 May) for the years 1975-1981[12]. It can be seen that a sustained temperature around zero was evident in 1977 and in 1980 for about 7 weeks, which would be enough to initiate a large-scale melt of the ice.

[12] Laurent Testut, via Antoine GUILLOT, INSU / Division Technique,Batiment Institut Polaire,FRANCE personal communication.

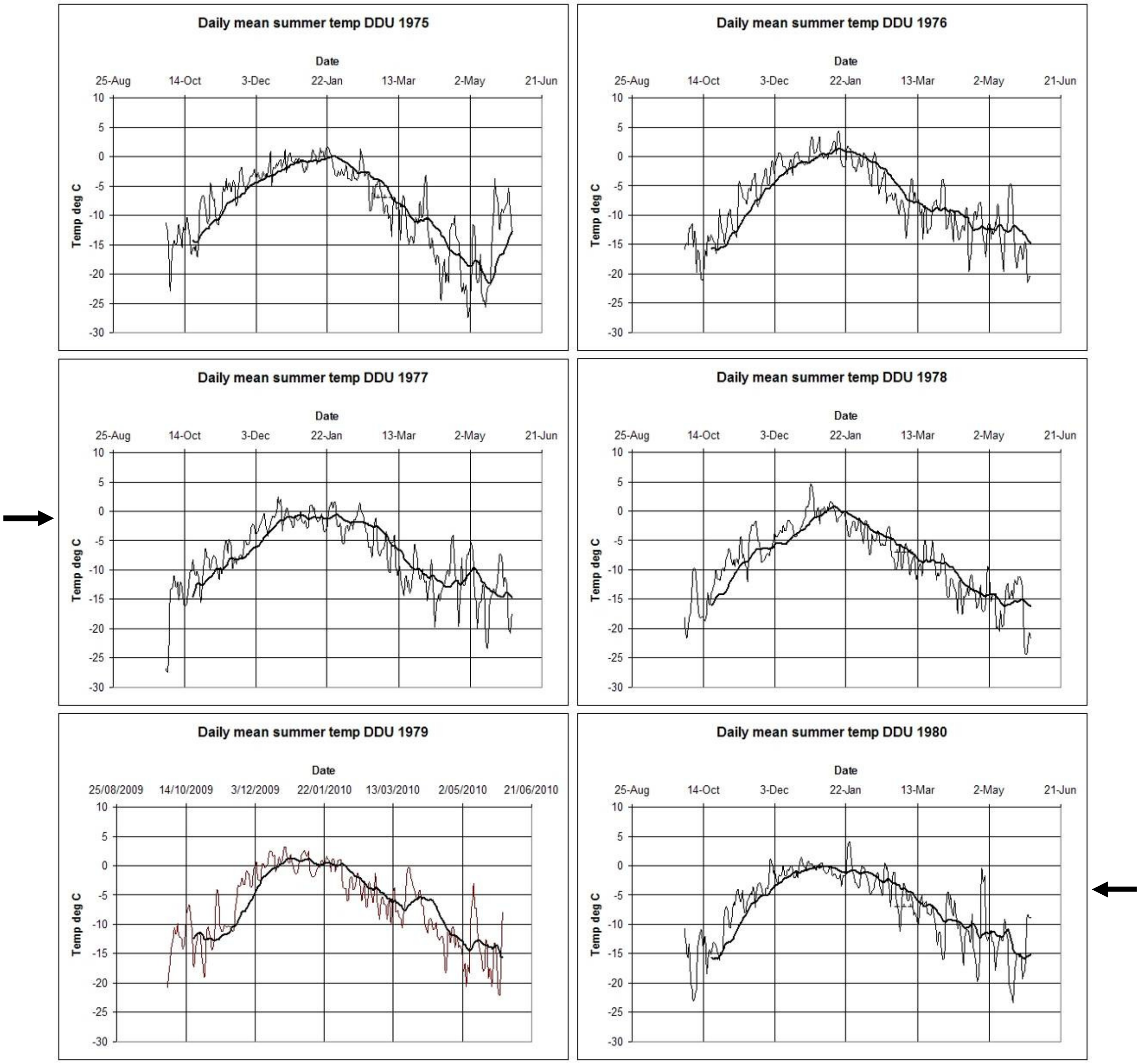


Figure 33 ***Daily mean summer temperatures from Dumont D'Urville station between 1 October and 30 May for the years 1975-1981. A 20 day moving average has been applied to the data (heavy line). Note that each year shows a peak around 22 January except for 1977 and 1980 when temperatures around zero are sustained for a period of about 7 weeks. Since Cape Denison temperatures are higher (by up to 10 degrees) compared with DDU this is evidence in support of the hypothesis that a large-scale ice melt could have occurred sufficient to free the air tractor from the ice.***

Amount of ice surrounding the air frame

It is worth getting in perspective just how deeply the air frame was buried. The picture from 1976 shows about 500mm of the frame sticking out of the ice. When compared with the earlier picture it can be appreciated how much ice surrounded the frame.

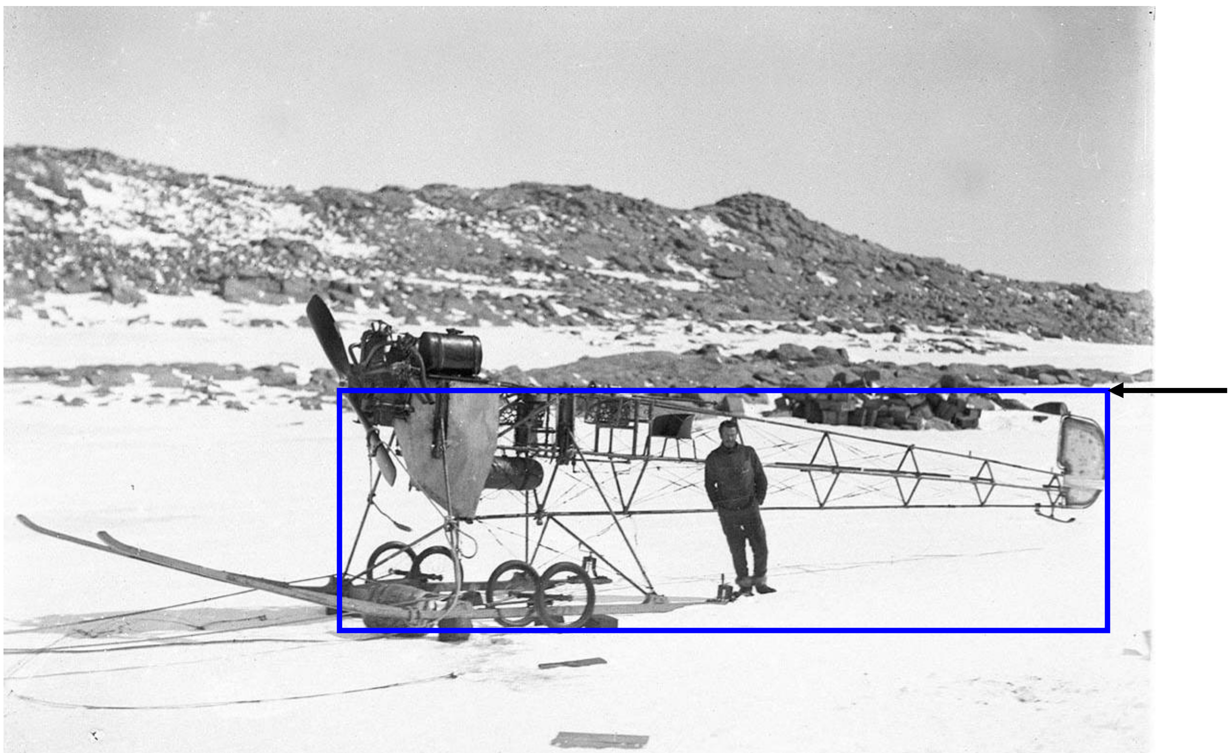


Figure 34*: Comparison between the photo of 1911 and 1976 (arrow shows ice level) show the extent to which the air frame was buried in the ice. This is a huge amount of ice, roughly equivalent to the volume of a sea container.*

The pictures from 1913, and from 1931 show that the bottom of the frame was encased in ice. Essentially what this means is that the frame is not going to move unless it melts into the ice (or the ice is scoured away by the wind – discussed below), and furthermore, since the ice is not glacial, the only direction the frame is likely to go is downwards.

Comparison between the 1911 pictures, and the 1976 picture give us an estimate of how fast the frame was sinking and overall it seemed to be travelling downwards at 50mm per year. This means that by now it would have theoretically travelled downwards about 1m deeper than in 1976. This is still well within the reach of the GPR scans, and, since it was not found, something must have happened between 1976 and 1981 when other visitors arrived.

The effect of wind on the frame

The winds at Cape Denison are the strongest ever recorded at sea level on Earth[13], and cannot be discounted as a factor in possible movement of the frame.

The tractor frame was relatively light – it was, after all, designed to fly, but the frame had little wind resistance since it was made of struts. If it had been freed from the ice by melting, or by the ice being scoured away, and was exposed to winds of the sort of strength recorded at Cape Denison, there are two possibilities:

a) It could have blown some distance into the harbour. It would then be likely to have been scoured out by the next years' ice breakup.

b) On the other hand the prevailing direction of wind during the summer months is about 120 degrees, which could have blown it north-westward, in the direction of the probable channel in the rocks. It could therefore still be stuck in that channel, or among the rocks.

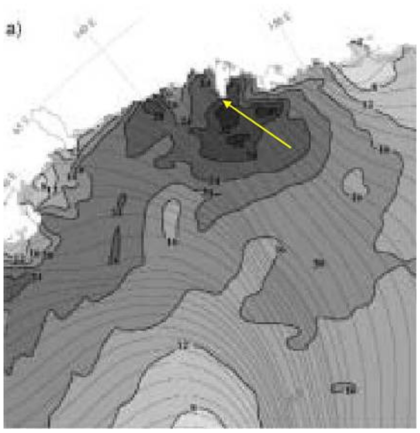


Figure 35: Wind speed estimates at Cape Denison. Arrow shows the estimated position of the air tractor frame and the direction of prevailing summer winds. The air tractor would be in the path of this wind if it were exposed in a summer melt. The air tractor happens to be in the area of the strongest sea-level winds ever recorded on Earth. If the ice melted and deposited the frame on the rocks, or if all the ice were scoured from the frame, and it were free to move, then the wind may have moved the frame.

Despite this possibility it should be remembered that the frame had been sitting on the ice at Cape Denison since it was abandoned in 1913. It is unlikely that all parts of the frame would melt out of the ice at once, allowing it to be blown in the wind at least 10m, more like 20-30m to the edge of the harbour. It would also have to fall into deep water which would freeze in the winter, trap the frame, and blow out to sea the next spring. Melting ice usually frees objects unevenly, so that something is always stuck. According to the report of Neil Young the ski attachments were seen and then disappeared, so the frame could not have skidded on its skis if freed from the ice.

Nevertheless, if somehow the frame did enter the harbour, and was encased in winter ice, it is very unlikely any trace of it remains, since all the ice in the harbour blows out to sea in the spring.

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[13] On the extraordinary katabatic winds of Adélie Land Wendler, Gerd; Stearns, Charles; Weidner, George; Dargaud, Guillaume; Parish, Thomas Journal of Geophysical Research, Volume 102, Issue D4, p. 4463-4474 **http://adsabs.harvard.edu/abs/1997JGR...102.4463W**

The behaviour of ice in Boat Harbour

The harbour ice reportedly forms from the bottom up as well as top down, and when the ice breaks up in summer it tends to take the whole lot with it and scouring the bottom of Boat Harbour. This has been reported to happen very quickly - within 3 hours[14]. This implies that the air tractor frame could have gone out to sea in a block of meltingwinter ice.

This could not have happened unless the frame was blown 20-30m from its 1976 position into the harbour.

The sudden breakup of the ice, and scouring of the harbour does not happen with the ice around the edges of the harbour. This ice is slowly eroded by seawater from the bottom up, leaving large overhanging shelves that eventually break off. If the frame is resting on the bottom, perhaps in a channel or on the rocks it is likely to still be there, protected from the scouring effect by the surrounding rock.

Figure 36: While the body of ice in Boat Harbour disappears quickly, scouring the bottom, the ice round the edges behaves differently. It erodes from beneath forming large overhangs which break away during summer. This picture was taken on 2nd Jan 2009. The air tractor search was behind the rocks, arrowed. If the frame had melted down to the harbour bottom in this location it would not have been taken out to sea in the early ice breakup. (Photo David London)

[14] McIntyre D and M "Two below zero" p 189

Position of the trench

The position of the trench was accurately measured by Peter McCabe and Ben Burdett (carpenters) with respect to the proximal corners of Mawsons Huts in order that it may be found again if necessary:

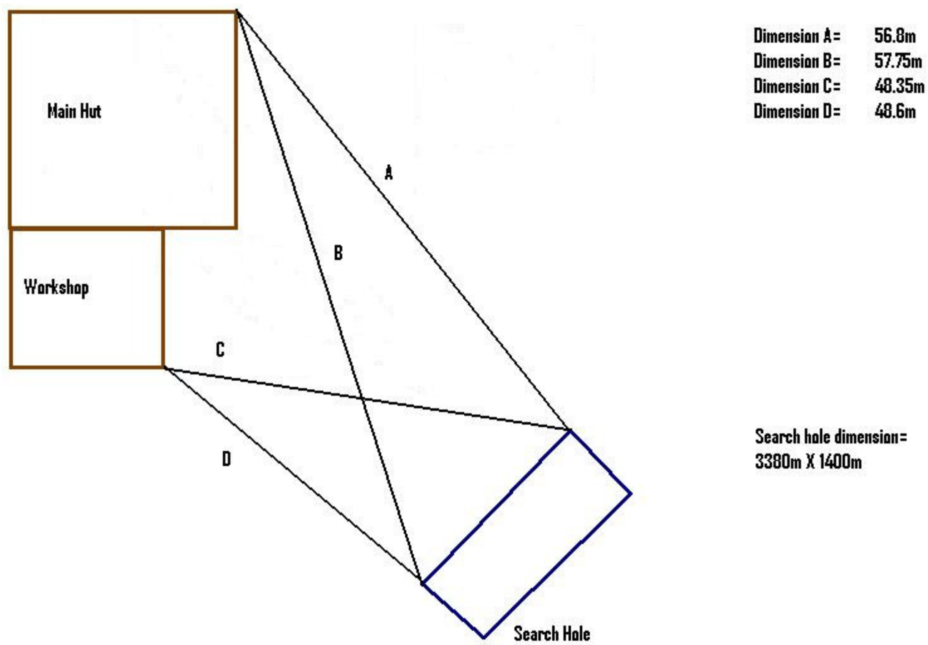

Figure 37*: measurements of the trench referred to easily recognisable fixed features at Mawsons Huts.*

Location of search areas

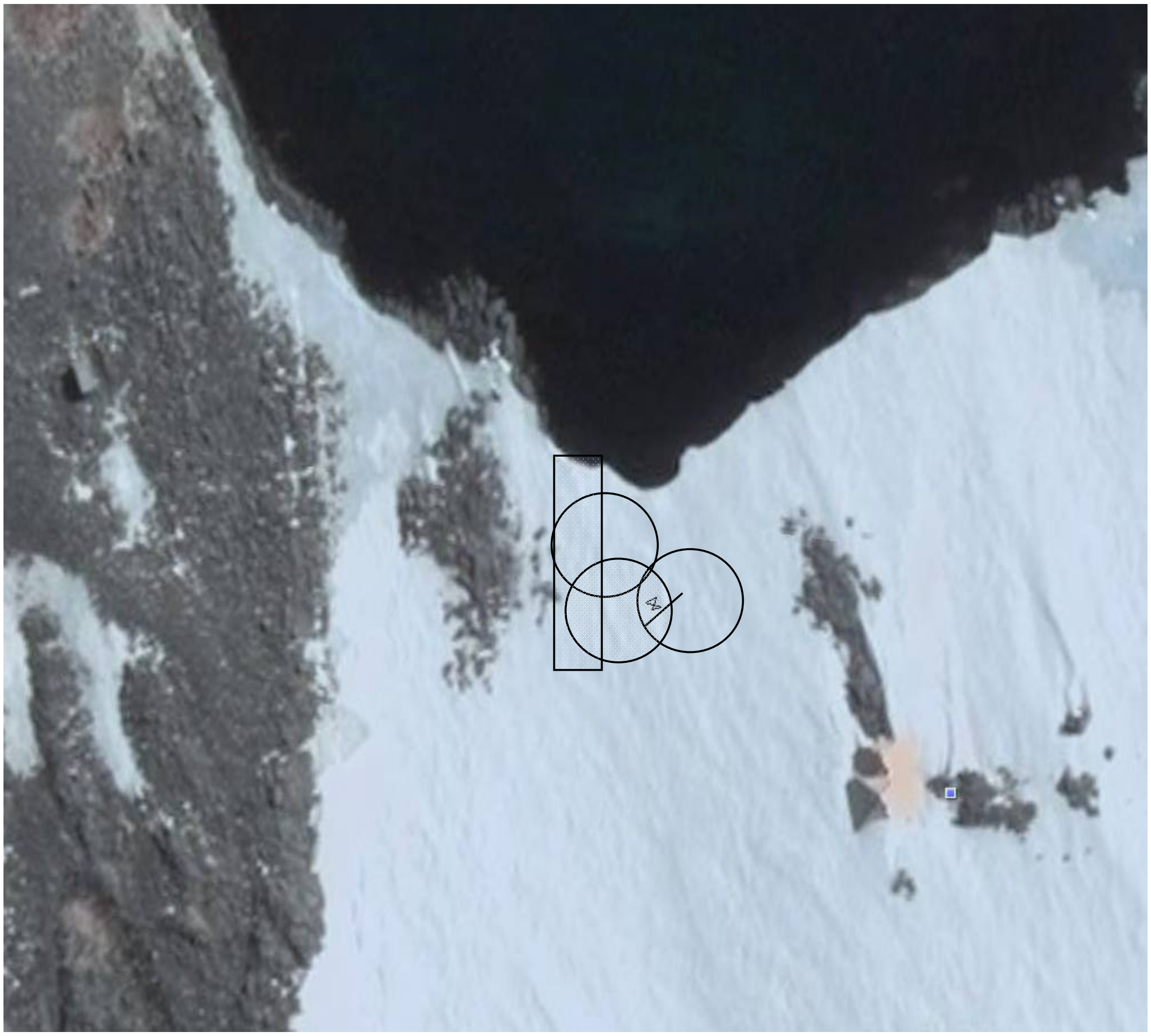

Figure 38: This shows the location of the search areas superimposed on a Google Earth picture from 295m. The total area searched amply covered the possible position of the air tractor. The circle closest the harbour was the first search, the two lower ones the second search. The cross at the intersection of the two lower circles is the estimated position of the air tractor frame. The exploratory trench we dug was approximately where the diagonal line is.

The channel found on the radar scans and discussed in the text runs approximately in the area of the long rectangle.

What happened after Bob Reeves visit in 1976?

The last picture we have of the air tractor was in 1976. There was another expedition by Dr David Lewis in 1981/2 (Oceanic Research Foundation) in Dick Smith Explorer. Dr Don Richards, who was First Mate and Radio Operator on the 1981/2 expedition cannot remember any sign of the air tractor, and was sure they would have seen it, since they were well aware of the history of the Mawson expediton, and examined the area closely[15]. The Project Blizzard expedition in 1984 found no sign either.

The cameraman on that expedition, Mal Hamilton[16], conferred with Don Richards, and between them they were certain there was no trace of the air tractor when they visited. A picture taken by Mal of the area where the air tractor was in 1976 clearly shows unbroken ice (below).

Figure 39: Dick Smith Explorer in Boat Harbour in summer 1981/2. Note the level of the ice in 1981. It is roughly the same as in 1976, and the frame should have been visible in 1981. Dr Don Richards, the First Mate and Radio Operator on the Explorer, and Mal Hamilton, cameraman, both report that there was no frame visible in 1981/2. (Photos Oceanic Research Foundation 1981, R image from National Geographic April 1983 p554)

The air tractor disappeared from view sometime between 1976 and 1981. The data supports the hypothesis that the air tractor sunk in the ice significantly faster, and perhaps the surrounding ice disappeared entirely, some time in that 5 years. Absence of proof is not proof of absence of course – but the GPR findings show that the frame was certainly absent in 2008.

[15] Dr Don Richards, personal communication.
[16] Mal Hamilton, personal communication.

SUMMARY OF RESULTS

1. Two trenches were dug down to 1.7m and 2.7m. The first positon was too close to the sea. GPR showed a promising shape, which turned out to be a hard ice layer at 1.5m.

2. After the first hole came up empty the original pictures of the Air Tractor, taken by Campbell in 1931 and Reeves in 1976 were examined. From these 3 transit lines were constructed, based on easily visible, well separated points. All 3 lines met at one spot, and all were sensitive to translation and therefore useful. It seems likely that this is the spot where the frame rested since at least 1931, and possibly 1913, until 1976. The last known photograph is by Bob Reeves in 1976.

3. The expedition by Dr David Lewis in 1981 did not find any sign of the Air Tractor. Project Blizzard in 1984 found no sign either. Reeves, in a second visit in 1987, did not find it.

4. Pictures were taken by Dr Ian Godfrey of a melt in 2002, where a lot of rock was exposed. With the help of a professional photographer (David London), photographs were taken of the landscape from the same positions and the pictures superimposed. This established that the Air Tractor was sitting on ice near a melt creek, and not on rock.

5. Pictures from 1931 and 1976 confirm that the ice in the shore area is not glacial, so the frame has not gone into the sea with ice movement.

6. The GPR was capable of reaching to about 5m below the surface, and should pick up a tubular steel frame 6m long by about 1m wide.

7. In the second search two overlapping scans were done, each of 17m radius over the spot where the frame was estimated to lie. A significant feature was seen at a depth of 2.5m in the place estimated for the plane, and a 3m x 1m trench was dug down to 2.7m. The previous hard ice layer at 1.5m was found, and another layer was uncovered at 2.5m. A metal detector was used in the hole but no signal returned. The dig was abandoned.

8. The floor of the trench was surveyed and found to be at high tide level, and ice containing seaweed fragments was found at this depth. This means that liquid water was present at some time, and that it was likely to be seawater.

9. A study of the temperature records from Dumont D'Urville (DDU), the French base 200km away, show a significant rise in summer temperature to around freezing in the 70s and 80s with a peak about 1980, and a sustained temperature for about 7 weeks in 1977 and 1980. Comparison between DDU records and those taken by MHF expeditioners suggest that Cape Denison temperatures are up to 10 degrees centigrade higher, but otherwise follow a similar pattern.

10. The result from radar scans at the level of high tide – the bottom of the hole – suggest that there is a channel in the rock close to where the air tractor frame would lie if the ice were to melt.

11. If the frame were freed from the ice it may be subject to wind forces and may move north and west toward the harbour.

12. The main body of ice in Boat Harbour can break up and blow out to sea quickly, taking any debris with it. However the ice round the shores is eroded from the bottom and forms protruding ledges. If the air tractor frame is in the harbour at the edge of the bay it is unlikely it will be subject to movement of the main body of ice. It is probably still in place.

13. The Air Tractor seat was found about 100m away on rocks at the other side of the bay and catalogued in 2008 by Anne McConnell. This was a home made seat in addition to the two existing seats in the plane. It was clear from the photographs of the abandoned frame that the third seat had been cut from the frame, so its discovery does not imply any movement of the main frame.

Discussion

The frame of the Air Tractor was not found despite the precision and reliability of the transit lines, and the depth of radar scans extending to well below high tide level. The search area was certainly large enough to cover any translation of the frame in the years since 1976.

GPS error

Errors in the GPS readings would have affected the results, but the Trimble GPS provides an accuracy of 13 decimal places. This does not mean the GPS was accurate in terms of its position on the land, but it means it was capable of reading the satellites to that accuracy. As long as the readings were self consistent within the search pattern, any 'dither' was acceptable. It would have been preferable to use Differential GPS, but this was not available.

Ground Penetrating Radar

The radial search technique was developed to allow the operators to concentrate on handling the cart and the equipment in the conditions. This is in contrast to the standard way of searching a grid, which was soon discarded as being cumbersome and unworkable during trials in Hobart. The central pole was a piece of heavy duty plastic agricultural pipe whose diameter of 150mm gave a spacing between the spirals of 470mm, matching the resolution of the radar and providing optimal search parameters. Smoothing the ice surface avoided any error caused by displacement of the aerial due to the sastrugi.

The radar aerial used was 250Mhz which has a resolution of about 45cm, but a depth penetration of about 5m. It was thought that the frame contained enough metal, which is radar reflective, at varying angles to the beam and thus likely to be seen. No tests were done to confirm this assumption, and it may of course have been that the radar simply could not visualise the frame. Neither was the radar unit placed at the bottom of the trench, which would have considerably extended its downward scan, albeit over a very small area.

Subsurface topography at the position of the scans
The scans show clear evidence of flat ice at around 2.5m abutting the rock band next to the search area. The second trench was dug to high tide level, and contained seaweed consistent with the formation of sea ice. This suggests that there is a channel entering the rocky promontories between which the search was carried out.

If the air tractor frame were to be deposited downwards in this area due to a significant melt, it would lie very close to a channel in the harbour. It would be possible for the frame to fall (or be blown) into the channel, and it would therefore be possible that the frame is currently resting at the depth of Boat Harbour sea bottom (about 6m), which is below the level at which the present radar equipment can penetrate.

Melting of the ice beneath the frame
The temperature records at Dumont D'Urville were used as a proxy to Cape Denison. Cape Denison temperatures are significantly higher. It is possible that a big melt between 1976 and the first visitors in the early 80's exposed the frame of the air tractor. When the temperature rises above zero the ice melts very fast in the area, and in a few days the whole surface of the ice sinks noticeably. If Dumont D'Urville experienced temperatures around zero for about a couple of months, then Cape Denison would be around 10 deg C higher, which would easily melt most of the ice on the harbour foreshore. This occurred in 1977 and 1980.

Ice melts out of the centre of the harbour, though not at the edges, so if the frame was deposited among the rocks it should still be there.

Wind blowing the frame into the harbour.
It must not be forgotten that the winds at Cape Denison are incredibly strong. The winds did not shift the frame in the 63 years between the departure of Mawsons' expedition and the 1976 photograph of Reeves. However, it remains a possibility that the wind scoured all the ice down to the bottom of the frame, and simply blew it out into the harbour.

The most likely outcome however, is that there was a big melt in 1977, which freed the frame from its enclosing ice. The frame then fell into the sea and remains at the edge of Boat Harbour, deeper than the GPR can penetrate.

Figure 40 ***If the reasoning in this report is correct, then the Air Tractor is still in the ice, probably in a channel in the rock, at the edge of Boat Harbour in the area shown by the arrow on the left and similar to the one illustrated on the right, which is at the base of the rocks near Grenholme hut (photo Don McIntyre 'Two below zero').***

<u>CONCLUSION</u>

It is likely that the frame stayed in one place for at least 63 years (1913 – 1976). The fact that the plane was not found this year suggests three scenarios of decreasing probability:

1) A significant melt occurred sometime between 1976-1981, probably 1977 or 1980, which freed the air tractor from the ice. The frame then fell into the sea at the edge of Boat Harbour, where it remains encased in ice.

2) The frame was not detectable in the areas searched using the Ground Penetrating Radar, either because it is deeper than 4m or GPR is not the right technology to use.

3) Strong winds scoured the ice from the frame, which was then blown onto the harbour ice and subsequently taken out to sea in the summer melt.

<u>Suggestions for a further search</u>

- It is likely that a magnetometer would be a preferred option for a renewed search. Expert advice should be taken on its suitability for this purpose. The equipment should be well prepared and tested before deployment.

- If nothing is found scanning from the surface, then the search should include digging a trench in the most likely place for the frame (perhaps the 'channel' area). The trench dug this year could also be re-excavated (it should be relatively easy to do). By digging two trenches and using the scanning device inside the holes, the search capability is brought 2-3m deeper, and thus closer to the likely position of the frame.

- If the frame has moved then it is unlikely to have gone anywhere but down and/or into the edge of the harbour. It would therefore be useful to make a sonar survey of Boat Harbour, which is about 6m deep. A visual scan could also be made in calm water using either an underwater viewing tube or an underwater camera.

- If divers are available (perhaps in conjunction with the French – it was after all a French aeroplane), then a full visual search of the harbour can be made.