Anomalous Echoes Captured by a B-52 Airborne Radarscope Camera: A Preliminary Report

(Part 3)

Martin Shough

6. Interpreting the unidentified echoes (cont.)

k) anomalous propagation

Here 'anomalous propagation' or AP is broadly defined to include various atmospheric refraction and reflection effects that could give rise to phantom targets. Several passages in the Blue Book file materials refer to a "moderate temperature inversion" or a "pretty good inversion". The AFR 80-17 telex report has the entry:

> A MODERATE TEMPERATURE INVERSION FROM APPROXIMATELY 2,000 FEET ABOVE THE SURFACE TO APPROXIMATELY 5,000 FEET, THAN (sic) A FAIRLY STANDARD ADIABATIC LAPSE RATE THROUGH THE UPPER LEVELS

Blue Book typically appealed to any evidence of temperature inversion to write off cases as probable AP, often without much regard to either phenomenology or quantities. And early in the investigation Col. Quintanilla remarked, covering a couple of bases at the same time: "I'm pretty sure it was either caused by an internal radar malfunction . . . or because of the inversion he might have also picked up an anomalous blip." But unusually, in this case the official evaluation did not in the end place great emphasis on radar AP or electronic phantoms and Blue Book came down in favour of a ball lightning-type plasma.

Nevertheless the conditions need to be investigated, and it should be said first of all that the above reliance on temperature lapse rates alone is not at all meaningful since humidity is a much more important contributor to radar refractivity.

Secondly the upper-air weather data (though not the surface data) given in the Blue Book file were "obtained from Glasgow", an airfield in Montana some 250 miles west of the location of the incident, and so although possibly indicative are not guaranteed to be relevant.

Thirdly the time of Glasgow balloon release is not stated.

Fourthly the original Glasgow rawinsonde data are not presented; instead those given in the file occur only in a Memo for the Record, a typed record (with not-wholly-unambiguous handwritten addenda) of a telephone conversation in which Col. Werlich passed on to Lt. Marano, FTD, information "obtained" from Glasgow in an unspecified manner by Sgt. Dickson of the Minot AFB weather office.

And fifthly, Quintanilla gives no thought to the physics or the ray geometry of these "anomalous blips" that might occur due to inversion conditions when the radar is flying some thousands of feet *above* the supposed inversion. Commonly energy from a radar on the ground which normally only "looks" at the sky may be bent or scattered back down to detect echoes from reflectors elsewhere on the ground. In this case we have a radar in the sky deliberately inverted to radiate most of its energy earthward in such a way as to be full of ground return in normal operation, so the usual assumptions may be misleading.

Radar refractivity profiles

To begin with, correct radar refractive index values were calculated from the Glasgow AFB temperature and dewpoint data in the file and the resulting *N*-gradient is graphed in *Fig. 13* below.

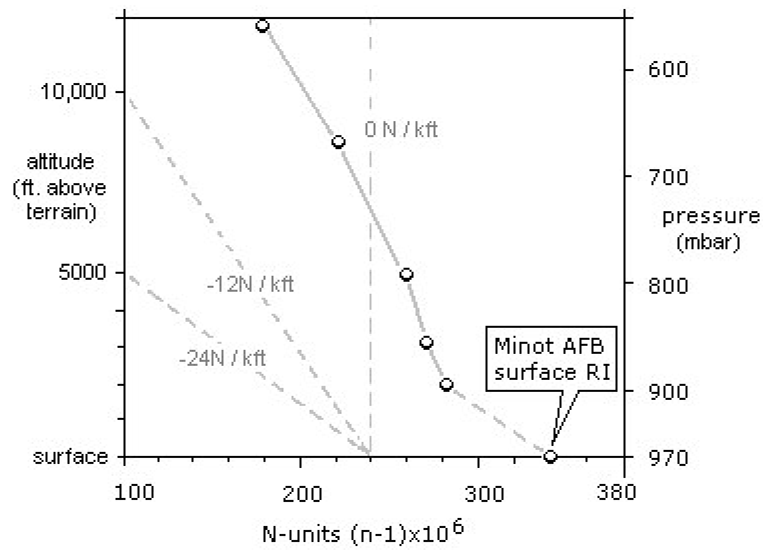

Fig.13 N-profile for Glasgow AFB, Montana, Oct 24 1968.

Constructed from Blue Book temperature and dewpoint data for five levels (time unknown), altitudes converted to equivalent pressures (36 mbar/kft) and N-values determined by nomogram. The dotted part of the profile connects the Minot AFB surface data for 0855 GMT. The limiting slopes of "normal" refractivity (mean -12N/kft) are indicated at left.

The radiosonde sampling levels are too sparse to give a very meaningful picture, but the main features of the diagram are:

- the average gradient for the first 2000 ft is just marginally superrefractive, but not significantly at -27.5 *N*-units per kft (the range 0 *N*/kft to -24 *N*/kft is considered the extent of "standard" refractivity);
- the conditions for trapping (about -48 *N*-units per thousand feet or greater) are nowhere indicated;
- above 2000 ft (height above terrain, so about 3680 ft MSL) the refractivity

gradient remains quite close to the mean for a standard atmosphere.

[Note that the equivalent pressures calculated here assume a "standard atmosphere" of 36 mbar/kft (Wylie, 1952) chosen to be close to the empirical lapse rate found for the Bismark ND soundings (see *Tables 5/6 below*).]

altitude (ft above terrain)	equivalent pressure (mbar)*	temperature (°C)	dew point (°C)	relative humidity (%)	refractivity (N-units)	refractive index gradient (N / kft)
surface	970**	0	-2.0	86	340	
						} - 27.5
2000	898	+4.0	-3.5	58	285	
						} - 12.5
3200	855	+10.5	-2.5	40	270	
						} - 5.5
5000	795	+9.0	0	53	260	
						} - 10.0
8500	664	+1.0	-5.0	75	225	
						} - 15.0
11500	556	+1.0	-8.0	64	180	

* using standard lapse rate of 36 mbar/kft (Wylie, 1952)

** estimated from 30.12 In Hg Minot AFB altimeter setting cited for 0355 CDT

Table 4. Radar refractive index data for Glasgow/Minot

Calculated from Air Force temperature and dewpoint readings for Glasgow AFB, Montana (aloft, time unknown) and Minot AFB, ND (surface, 0855 GMT). Pressures are estimated and indicative only.

So there is no sign in the Glasgow radiosonde data of the elevated anomalous propagation conditions inferred by Blue Book from the temperature figures. Very marginal superrefactivity is indicated through the first 2000 ft above the surface in *Fig. 13*, but this depends on the validity of importing Glasgow balloon data and Minot surface data into the same diagram. Stratification of stable night-time air can extend over very large horizontal distances, but this assumption is obviously doubtful.

Given the limitations of the data and the relative remoteness of Glasgow from Minot some coherent data from a nearer weather station were considered desirable.

Enquiries to the US National Climate Data Centre, Asheville, NC., established that the nearest extant balloon release data for Oct 24 1968 were from Bismark, ND., approximately 120 miles SSE of Minot AFB. Copies of the Bismark data for 0000 hrs and 1200 hrs on the 24th were obtained and used to populate *Table 5* and *Table 6* below (the complete NCDC dataset is reproduced in *Note 10*).

altitude (ft above terrain)*	pressure (mbar)**	temperature (^oC)	dew point (^oC)	relative humidity (%)	refractivity (N-units)	refractive index gradient (N / kft)
surface	966	+3.9	-3.0	73	280	+11.3
443	950	+2.8	-9.0	57	285	0.0
1857	900	-1.7	-2.0	96	285	-13.5
3343	850	-4.8	-5.0	99	265	0.0
3494	845	-5.1	-5.0	100	265	-19.9
4900	800	-7.3	-22.0	47	237	-10.6
5561	779	-8.0	-30.0	32	230	-8.7
6480	750	-9.4	-35.0	26	222	-6.6
8287	700	-11.9	-36.0	27	210	-8.3
10,088	650	-14.8	-29.0	46	195	0.0
10,187	649	-14.9	-29.0	46	195	-8.2
12,024	602	-14.4	-36.0	31	180	0.0
12,126	600	-14.6	-37.0	30	180	-4.7
14,255	555	-17.7	-41.0	27	170	-6.4
16,600	500	-21.0	-47.0	23	155	

*Converted from geopotential metres MSL. Surface is surveyed altitude of Bismark Airport, 1661 ft MSL.
** Converted from kilopascals

Table 5. Radar refractive index data, Bismark ND, 0000 Oct 24 1968

Temperature, pressure, RH and heights from DS-6201, US Rawinsonde Observations, courtesy of National Climatic Data Centre, Asheville, NC.

The Bismark datasets have temperatures recorded up to heights of 11 and 50 mbar, but no relative humidities are shown above 350 and 308 mbar so these upper levels are unfortunately of no use. In any case the *N*-profiles graphed in *Fig.14* below are terminated at 500 mbar as this was the limit of the refractive index nomogram used. (Informally, it is fair to say that the few levels not graphed indicate continuing trends, with one small inversion - only a fraction of a degree, just off the top of the 0000 hrs diagram at about 450 mbar - and no noteable discontinuities in the dew point.)

altitude (ft above terrain)**	pressure (mbar)*	temperature (^{o}C)	dew point (^{o}C)	relative humidity (%)	refractivity (N-units)	refractive index gradient (N / kft)
surface	963	-2.8	-6.0	85	300	
345	950	+0.0	-5.0	77	290	} -28.9
377	949	+0.1	-6.0	74	290	} 0.0
1001	927	+1.8	-3.0	80	290	} 0.0
1785	900	+0.0	-3.0	87	278	} -15.3
3281	850	-2.7	-4.0	91	265	} -8.7
3396	846	-2.8	-5.0	91	265	} 0.0
4150	823	-0.4	-25.0	29	238	} -20.3
4865	800	-1.3	-26.0	29	240	} +2.8
6545	750	-3.3	-29.0	26	220	} -11.9
8330	700	-5.3	-33.0	23	205	} -8.4
8907	684	-6.1	-35.0	22	200	} -8.7
9859	659	-5.8	-34.0	22	190	} -10.5
10,251	650	-6.2	-23.0	43	192	} +5.1
11,105	628	-7.3	-9.0	93	190	} -2.3
12,283	600	-8.2	-9.0	97	180	} -8.4
14,288	556	-10.0	-14.0	79	170	} -5.0
14,518	550	-10.6	-15.0	81	170	} 0.0
16,883	500	-14.7	-21.0	72	152	} -6.9

*Converted from geopotential metres MSL. Surface is surveyed altitude of Bismark Airport, 1661 ft MSL.
** Converted from kilopascals

Table 6. Radar refractive index data, Bismark ND, 1200 Oct 24 1968

Temperature, pressure, RH and heights from DS-6201, US Rawinsonde Observations, courtesy of National Climatic Data Centre, Asheville, NC.

The results of these Bismark observations bracket the sighting period of interest. Overall, of 32 pairs of layers compared, only in four cases are *N*-gradients outside the range for a "standard" atmosphere indicated. These occur in the first few hundred feet above the surface in both diagrams, and at about 4,000 and 10,000 ft in the second.

The earlier 0000 GMT diagram shows an interesting narrow *sub*refactive surface layer; whilst the most relevant 1200 GMT diagram (~2 hrs 54 mins after the time photographed on the radarscope clock) shows a very marginally *super*refractive surface layer of similar depth, in fact not very dissimilar to the surface value shown in the compound Minot/Glasgow profile in *Table 4*, though over a narrower sample range in this case.

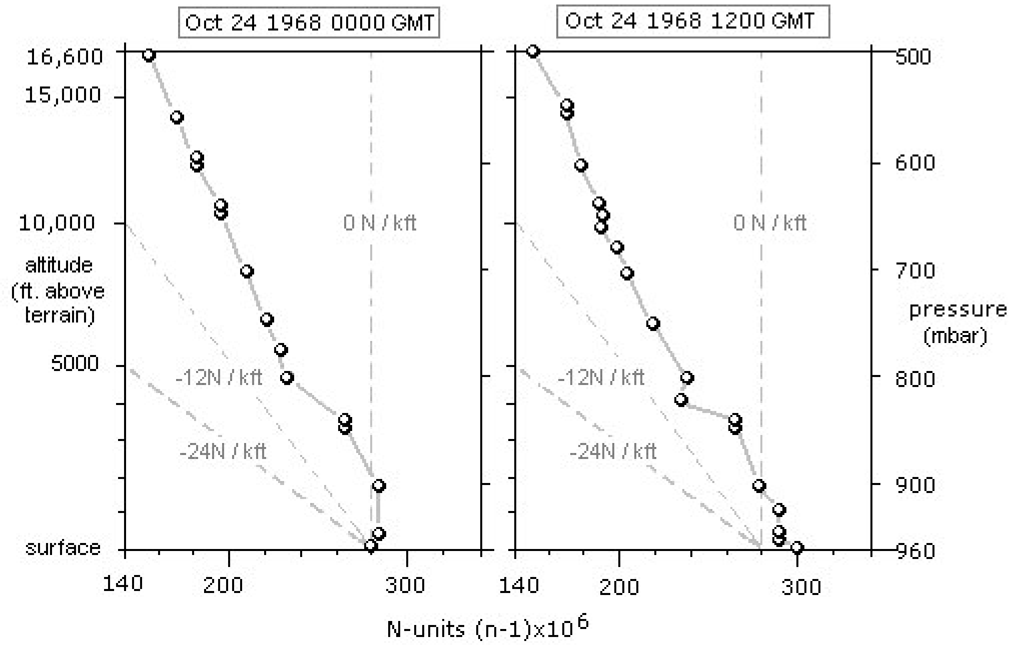

Fig.14. N-profiles for Bismark, ND, Oct 24 1968
heights converted from geopotential meters

The elevated 1200 GMT discontinuities are both subrefractive (i.e., tending to bend raypaths upwards away from the surface of the earth) and neither is more than a few *N*-units outside the "normal" range. None of these features appears likely to cause an increased likelihood of anomalous ground echoes on an airborne radar (in general, rather the opposite if anything), and there is no evidence of any RI discontinuities severe enough to even be detectable by direct backscatter, let alone as a very strong discrete echo.

Of course it is impossible to rule out the presence of undetected sharp layers of extreme *N*-gradient falling between the sample points. Such extreme layers, occurring below the flight level, could conceivably produce very unusual echoes by direct backscatter near normal incidence. Gradients in the order of tens of *N*-units/cm have been hypothesised in extreme conditions (for perspective, in terms of equivalent temperature - ~1 deg C per *N*-unit - this would be 100,000 times as steep as the steepest gradients responsible for normal optical mirage). Admittedly it strains credibility to suppose that such a backscatter echo, at an angle very far from the peak gain of the antenna (in the order of several 10' s of dB below the gain anywhere in the main beam), could yield a strong blip on the PPI of an airborne surveillance radar of modest power (see *Note 6*). But it is also true that the extreme limits of the power reflectivity coefficients of such layers in nature may be unknown, so the hypothesis should be investigated.

As will now be shown, even granting extraordinary power reflection efficiency it is very hard to see such a mechanism as a primary cause of a strong discrete echo of the kind seen. The main reasons for this conclusion are connected with the strength and discreteness of the *Phase B* echo (requiring a hot-spot of direct backscatter to the antenna at normal incidence) combined inconsistently with persistence of the echo off-centre at a constant bearing (indicating forward scatter away from the antenna at an off-normal incidence).

Backscatter from an hypothetical elevated layer of extreme N-gradient

As mentioned, the detection of local ground echoes by AP in the usual way is not an issue in this case. If the short-range unidentified targets within the altitude hole are local first-trip echoes (they do not have to be, but we come back to that presently), and as long as their displayed slant ranges are less than the aircraft altitude, then they must be echoes from airborne reflectors. For the B-52 altitude values found in the present analysis the *minimum geometrically possible* altitude of a such an airborne reflector at frame #773 is approximately 10,000 - 6375 = ~ 3625 ft, and at frame 782 is approximately 8700 - 5285 = ~ 3415 ft above the terrain. (Poher' s analyses of the scope photographs and B-52 flight track suggests a different B-52 position, but the way other variables are affected by this hypothesis means that it results in approximately similar values for the B-52 altitude, so this convergence is reassuring.) Furthermore these are not practical minima because they assume a reflector to be vertically below the aircraft, whereas the radar is emitting very little radiation in this direction because the antenna boresight is elevated in Station Keep mode.

The technical literature (*Section 4*) and the evidence of the photographs both suggest a rather sharp cut-off in antenna gain at a depression angle of about 45-50 degrees, consistent with the B-52 flight data (*Section 5*). If the target is within this main beam pattern then it must be significantly higher than ~3500 ft above the terrain. But of course gain will never be quite zero at any angle for any radiator, and we should perhaps consider that this apparent cut-off is not sharp at all ranges.

Because of practical limits of antenna design and mounting, the curve of gain *might* have minor lobes at undesirable angles far from the boresight that are insignificant in normal use but might pick up an echo from an unusual reflector at close range almost directly below the aircraft. If so the echo will paint on the PPI at the azimuth of the main beam at the time. Nevertheless even in a significant minor lobe the gain will typically be several orders of magnitude weaker than the main beam, and so a strong echo presentation - described by expert witnesses as comparable to or stronger than the echo from a very large jet in the main beam - implies that any reflector near -90 degrees elevation would have to be super-efficient in comparison to a large jet by at least the same several orders of magnitude.

What could this local reflector be, if not a large airborne object? In general one would expect the most efficient direct backscatter from a generally homogeneous plane reflector like flat terrain to occur with radiation incident at 90 degrees, meaning that given a power density that was (hypothetically) constant per unit solid angle the curve of reflected intensity would peak at the nadir vertically beneath the aircraft and diminish towards grazing incidence at longer ground ranges (*Fig.15*). If the plane of rotation of the antenna is horizontal above a plane reflecting surface, then in this ideal case the echo would have a "hot spot" perfectly centred on the PPI and diminishing in intensity with radial distance.

In the real case the antenna gain falls rapidly towards the nadir (as far as ground echo is concerned, approaching zero for practical purposes at around -50 degrees) and we know that the reflector must be >3500 ft above the terrain during the photo sequence. The approximate constancy of this altitude figure has been alluded to, and could be taken to suggest that the closure of slant range on the PPI is largely or even entirely due to the rate of descent of the B-52 in relation to a reflector which is roughly stationary in altitude at about 3500 ft or above. Is it possible that the reducing slant range to the UFO echo may be tracking the reducing vertical distance to a sharp layer of extreme *N*-gradient? There is no radiosonde evidence of such narrow layers, but they could fall between the sparse data points and such a layer could conceivably constitute a radio "mirror" causing direct backscatter to the radar receiver in the form of a hot spot of efficient reflectivity.

However another feature of the real case is that the successive echoes are not coincident with the scope centre. They are not even scattered isotropically about the scope centre as might be expected in the case of some random wander about the mean. In fact they are all tightly confined to a narrow azimuth, which is difficult to explain.

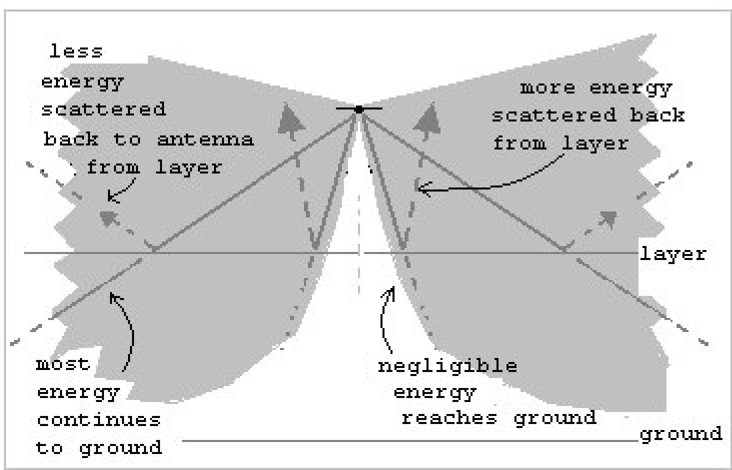

Fig.15 Geometry of hypothetical direct backscatter echo due to gain near normal incidence

Although gain near the nadir may be many orders of magnitude smaller than at the peak of the main lobe, direct backscatter efficiency increases rapidly towards normal incidence. In level flight with all other factors equal, the possible echo region would tend to be annular and concentric with the PPI centre.

The problem is trying to understand how to combine an extreme efficiency, which is more difficult to support the further the reflection geometry moves away from normal incidence, and which therefore strongly predicts echoes positioned isotropically in relation to the PPI centre, with the very pronounced anisotropy that we actually see. A concentric hot-spot is possible in principle; but the last thing one ought to expect is a compact echo, eccentric and restricted to one narrow azimuth on scan after scan within a margin of a degree or so, over a minimum of about half a minute and probably for as long as 6 minutes. *Ex hypothesi* this is hard to explain other than as a systemmatic deviation of the reflection geometry away from normal incidence. How can this occur?

One way in which this might happen is if the aircraft is flying with a slight angle of roll which could favour a consistently anisotropic backscatter, as shown exaggerated for clarity in *Fig.16*. But this appears to be ruled out because *a*) the aircraft is proven to be on a straight heading and the wings will be level, and more importantly because *b*) the antenna tilt is automatically servo-stabilised by pitch and roll signals from the navigation computer and aircraft attitude (to +/- 15 degrees) is irrelevant.

Could the computer compensation have been in error, sending inaccurate signals to the antenna tilt servos and causing an off-kilter rotation which favoured normal-incidence low gain echo returns from beneath the aircraft only when the boresight azimuth was on the left of the aircraft? Almost certainly not, because any deviation from horizontal in the antenna' s plane of rotation would cause an asymmetry in slant range to the ground at the edge of the altitude hole proportional to the cosine of this angle. For example, given a representative flight altitude of 10,000 ft, a tilt of only 5 degrees would cause the altitude hole radius to expand approximately 770 ft on one side of the PPI and contract by the same amount on the opposite side. This corresponds to fully 25% of the range ring interval, so even a small fraction of this 5 degree tilt should be measurable. There is no detectable asymmetry in the altitude hole - relative to the small overall eccentricity of the display caused by off-axis photography. (See also *Section 6.1* for a related issue.)

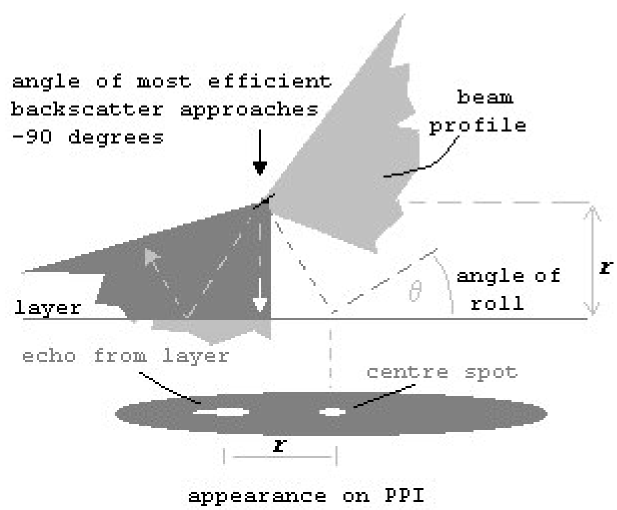

Fig.16. Eccentric display of direct backscatter echo due to failure of antenna servo-stabilisation

(Hypothetical pattern and exaggerated roll angle for illustration only)

So could there be an inhomogeneity in the layer, a domain or bubble of exceptionally high power reflectivity causing a persistent echo? The answer is again "no", because such a nearby feature of this hypothetical layer could not possibly maintain constant bearing from a B-52 travelling at 250 mph for at least 24 seconds (photo) and probably about 6 minutes.

The only options that appear to be left are to assume either *a*) a linear RI discontinuity parallelling the flight track of the B-52 at a slant range of about a mile, or *b*) an inclined layer tipped up to the ENE and down to the WSW, i.e. rotated around a horizontal axis parallel with the B-52 flight track (*Fig.17*), which might behave as a canted plane reflector so that a "hotspot" of extremely efficient reflectivity occurring at normal incidence could appear constantly offset to a bearing of 9 o' clock within a margin of about 1 degree over a recorded distance of about 2.5 miles and a well-reported distance some ten times as long.

Option *a*) is meteorologically bizarre; and as for option *b*), given that a layer with the necessary extreme efficiency of backscatter in a hypothetical minor radar lobe is already a reach of speculation, the added coincidence of a systematic reference of the layer inclination to the B-52 flight track, plus the unlikely compactness of the echo presentation, render the theory hardly credible in this writer' s opinion.

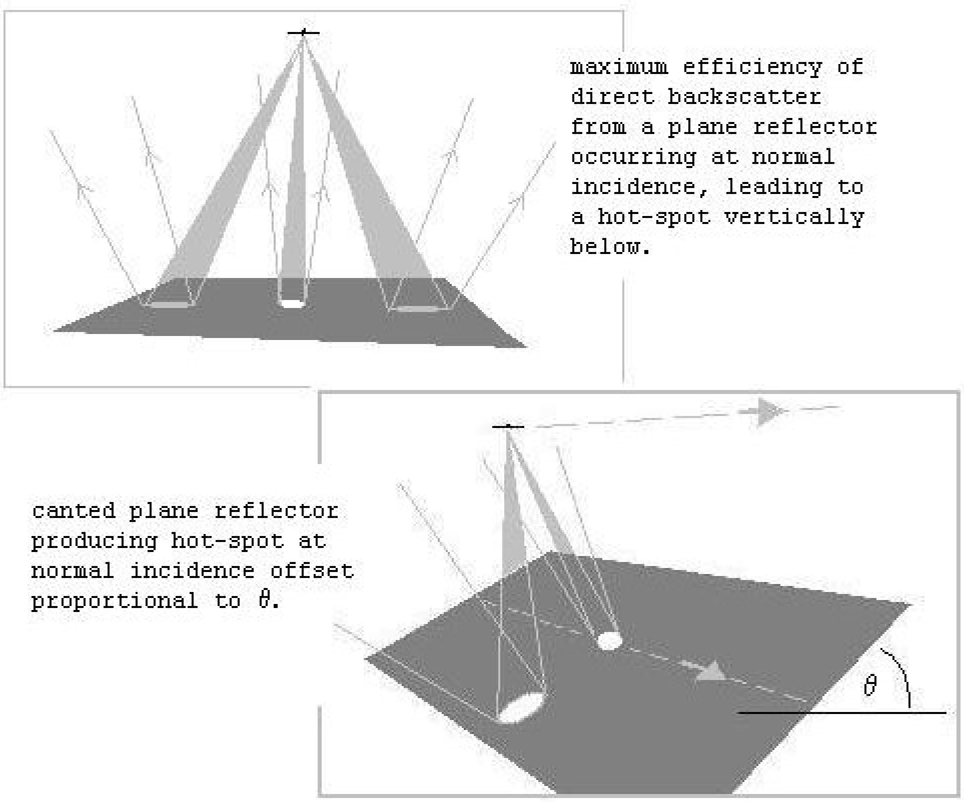

Fig.17 Offset backscatter hot-spot due to a canted layer.
(Purely illustrative and not intended to represent real radar coverage or realistic angles.)

Multiple-trip echoes from a remote reflector

If the echo is not a first-trip echo from a target inside the altitude hole (and assuming it is not a phantom due to malfunction or RFI) then it would have to be a target returning echoes from beyond the unambiguous range of the set, which would be 67.5 miles for the pulse repetition frequency of 1617 pps used in Station Keep mode. A reflector at range *r* would appear on the scope as a second-trip echo at a displayed range of *r* - 67.5 miles (i.e if *r* = 70 miles then displayed range = 2.5 miles) and could possibly account for the target falling back from about 40 to 39 degrees (+/- 1.0 degree) on the scope photos. Flight at ~ 250 mph for 24 secs. gives a travel of about 1.66 miles, which would subtend an angle of ~1.4 degree from a remote reflector at ~70 miles. Given margins of error this is not too bad and might explain the apparent stationing of the echo.

One other factor that might be suggestive of a remote fixed reflector is the behaviour of the echoes when first detected near the VOR approach beacon. Very roughly speaking, an echo was detected on the right of the aircraft on the outbound leg, which appeared somehow to move relative to the aircraft in such a way that after a 180 turn it reappeared on the left of the aircraft. Whilst this behaviour has quite a complex relation to the changing heading of the aircraft if considered as a moving object in the local sky, it has a natural relation to it considered as a multiple-trip echo of a static remote reflector. Basically (in the absence of detailed track data here) we could describe the relative motion by saying that the echo stayed in the NE.

The radar cross-section of the distant target implied by the multiple-trip theory is considerable. If the displayed echo was comparable in width of presentation to a large jet at 1.5 miles (the overall echo was described as larger than a KC-135 or a B-52) then the remote reflector responsible should be treated effectively as a point target and the returned power varies as the inverse fourth power, leading to a truly enormous ratio of efficiencies in the order 10^6. This implies an equivalent echoing area possibly as large as 10^9 square metres. One possibility might be echoes received from an isolated patch of high terrain.

Turtle Mountain, an upland area rising to 767 meters (2515 ft), on the Manitoba border, is at about the correct ~70 mile range, well inside the radar horizon (from an altitude of 20,000' MSL a radar beam intersects zero feet MSL at about 200 miles distance even in normal refractivity), and is near enough the azimuth indicated to be worth looking at. An echo around 7 degrees wide (frame 773) would correspond to a 2nd-trip echo from an area almost 9 miles across at the range of Turtle Mountain, and could conceivably be a reflection from the escarpment on the SW facing edge of the massif, which is the highest side. (Note that this would be especially possible if a Short Time Constant anti-clutter circuit is available to the operator [see *Note 5*]. However although STC was fitted to some bomb-nav radars of this vintage, there is no direct evidence that an STC switch was fitted in this case. It is also true that the rather large unbroken areas of generally featureless ground echo on all the photos do not suggest the use of such a filter.)

On this theory the doubling and/or elongating of the radar echo might be explained if a portion of the radar energy could be deflected by an elevated layer above the flight level, possibly a tropopausal layer above the usable radiosonde readings, returning a delayed echo from the mountain to the receiver *via* this slightly longer ray path. The ghost would appear on the same scope azimuth at a slightly greater range and would probably be intermittent as the efficiency of the raypath fluctuated. See *Fig.18* below.

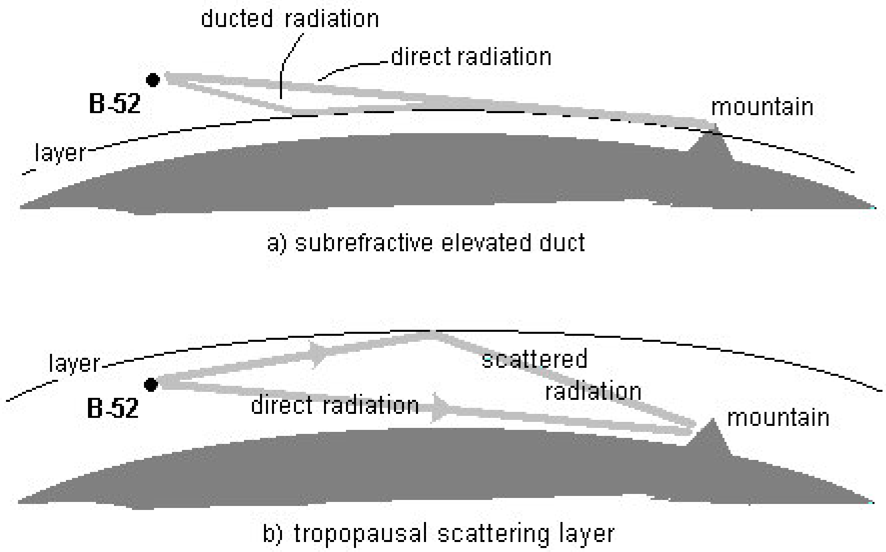

Fig.18. Schematic diagram of possible dual ray paths, of unequal length, giving rise to primary echo and simultaneous ghost echo of a distant mountain

Model a) is unlikely in view of the radar refractivity profile, but model b) is not ruled out.

It remains unproven that radiosonde readings taken 250 miles W and 120 miles SSE of the sighting location are relevant to conditions tens of miles *northeast* of the sighting location, of course, and there is no direct evidence at all of the required AP conditions. However with some reservations one could say that some variant of this theory is qualitatively consistent with the photo evidence.

On the other hand, over a period of some 6 minutes, as reported in the RAPCON transcript and elsewhere, this echo would have moved over an azimuth of 20 degrees or more. Whether this could still be consistent with an echo that kept station "off the left wing" as described is debateable.

Also the nearer edge of the primary blip is seen to approach the radar over the photo sequence. The expected change in displayed range and the duration of the echo would depend sensitively on the exact relative azimuth, and on possible fluctuations in the radar path length(s) due to changing propagation conditions; but even so the echo starts from about 2 degrees aft of 9 o' clock, so one would expect the displayed range to tend to increase slightly from frame 773, not to decrease as shown, and certainly not at a rate equal to the B-52' s descent rate over the local terrain.

It is also difficult to make this theory work in the face of evidence that the B-52 was still NW of Minot AFB prior to executing the planned low approach when the photos were taken, because only from positions SE of Minot AFB would Turtle Mountain begin to approach the displayed 40 degree azimuth. See *Fig.19* below. If the photos were taken at the very end of the radar event at the position indicated in the official file the discrepancy is about 30 degrees; at any earlier point on the flight track the match gets progressively worse.

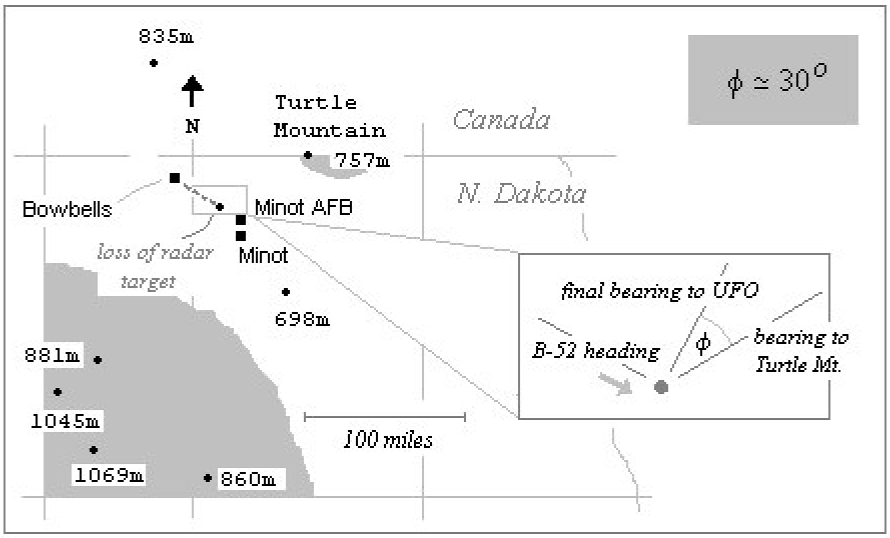

Fig.19. Relative bearings of Phase B echo and Turtle Mountains upland region

(illustration only approximately to scale)

Could the B-52 possibly have been SE of Minot AFB at the time? It is true that there is an unexplained apparent discrepancy between the times recorded in the RAPCON transcript and those photographed from the radarscope clock (see *Note 3*) and it would be possible to appeal to this timing ambiguity in order to place the B-52 SE of Minot at 0406. But to support the theory that the aircraft was already climbing out from its low approach over the Minot runway at this time we have to explain not only witness evidence (supported by the contemporanous RAPCON tape transcript) that the unidentified target disappeared finally whilst the aircraft was still on approach some miles to the NW of the unway, and internal photo evidence which indicates an aircraft altitude consistent with Col.Werlich' s 1968 reconstruction placing the aircraft at least 16 miles NW of the runway at this time (or even more in Claude Poher' s reconstruction which ties the ground feature in 783 to the shore of Lake Darling), but also the rather conclusive evidence (see *Section 5.ii*) that the B-52 is *descending towards* the runway during the photo sequence.

l) ghost echoes

Strong ghost echoes produced by multiple reflections ordinarily require first-trip returns from a primary reflector and a secondary reflector quite near the radar, such as another aircraft and an efficient corner-reflector on the ground. The displayed range to a ghost echo on the PPI will be half the total additive out-and-back path length of the signal *via* all reflectors. The ghost cannot possibly appear closer than the slant range to the secondary reflector, and generally the reflection geometry means that it will be much greater. Such ghosts typically do not last long as the critical geometry is unlikely to be sustainable due to relative motions of the radar and reflectors (Blackmer *et al*., 1969).

In this case the only evidence of an accompanying "aircraft" is the evidence for a UFO that we are trying to explain away, and the range from the B-52 to the ground at all relevant stages of the flight is far too great for echoes at ranges of a mile or so to be caused by secondary ground reflectors.

An exotic kind of ghost reflection geometry might conceivably arise if we can hypothesise an extremely sharp elevated scattering layer below the flight level, with an extraordinary power reflection coefficient near normal incidence, as we tried in *Section 6.k*. In this case a part of the B-52' s own airframe might act as primary reflector, and the layer as secondary, with a ghost being displayed at essentially the same range as the path length to the layer. The ghost range could therefore be as small as the ranges photographed, and it is also possible that in this way we could explain a very discrete and anisotropic echo which we found impossible to do by invoking a scattering layer alone, since the ghost will appear at the bearing of the primary reflector - in this case a part of the B-52, say a section of the wing or an engine pod.

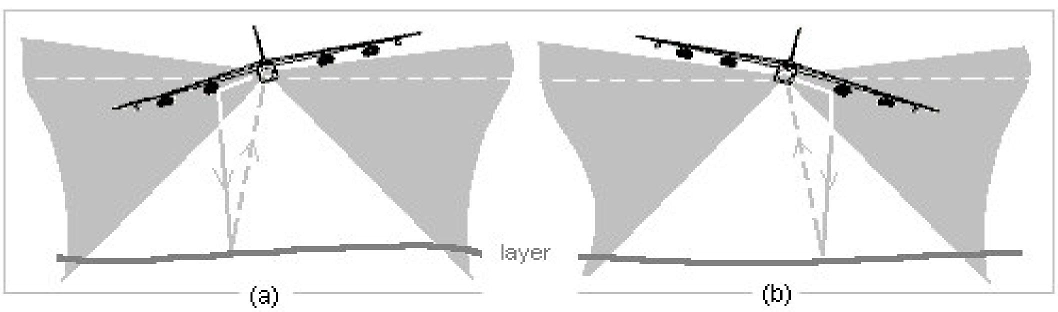

Fig.20. Roll of the aircraft in a turn, bringing wing down into higher-gain region of servo-stabilised antenna pattern.

Fig.20 suggests how this might occur due to the fact that the plane of rotation of the antenna is servo-stabilised by pitch and roll signals from the flight computer. In other words during manoeuvres the radar stays still, like the eye of a hawk, whilst the rest of the plane oscillates around it (within tilt limits of +/- 15 degrees).

Interestingly if we look at the positions of first detection of the radar UFO shown in *Fig.11* in *Section 5.iii* we see that it appeared off the *right* wing about the time when the B-52 would have been beginning to bank into a right hand turn (right wing dropping), and remained on the inside of the turn until about the point where the B-52 would have been banking into a *left* turn to compensate its overshoot and come back onto the approach heading over the WT beacon fix. At this point, with the left wing dropping, the echo reappeared on the *left* of the aircraft. As one wing drops it moves into a higher-gain region of the radiation pattern, possibly scattering increased energy down near the nadir, simultaneously as the opposite wing is rising out of the radiation pattern.

This is an intriguing hypothesis but, even given the possible existence of a layer with such extraordinary backscatter efficiency, it fails in several ways.

First, witness reports and contemporary documents describe a rapid closure of the echo off the left wing near the WT beacon, a speed in the order of at least hundreds of mph (Werlich' s map overlay) or thousands of mph (written statements) which can' t be explained by any change in the reflection geometry between aircraft and layer in a matter of seconds

Second, the persistent anisotropy of the echo geometry over the rest of the approach path is unexplained by an elevated layer, as already explained in *Section 6.k*. (In fact there we saw that this could only be explained - if at all - by a *failure* of the antenna servo-stabilisation leading to a canted plane of rotation; yet there is clear photogrammetric evidence that the plane of antenna rotation was horizontal during the radar film sequence, as it should be if functioning correctly.) The plane is during this time flying straight and level with no cross wind and thus zero or negligible roll.

Third, the geometry of a ghost reflection due to a layer below a descending aircraft does not allow displayed range to stay constant when the aircraft is flying at over 18,000 ft above the terrain *and* when it is less than half this height near the end of its approach.

Finally, and conclusively, the smallest bearing angle from the radar in the B-52 nose to any part of the airframe in the radar pattern (an engine pod) is fully 40 degrees aft (see *Fig.21*). Since a ghost echo is always displayed at the azimith of the primary reflector it is not possible for the UFO echo, always many degrees ahead of this angle, to be a ghost produced by reflection from the B-52 airframe.

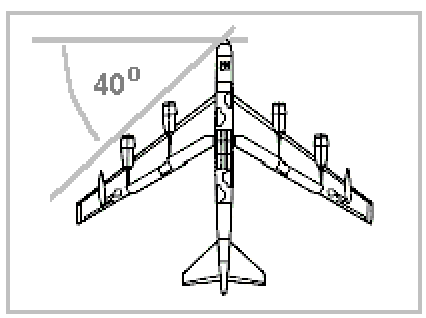

Fig.21. Plan of B-52 showing smallest bearing angle to any part of the airframe from the nose-mounted radar.