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

(Part 4)

Martin Shough

7. Conclusions

The reconstruction in *Section 5.iii* means that the supposed fast track 771-772 occurs not at the start of the event but towards the end, and bracketed by two periods of extended stationing by the 40-degree *Phase B* echo. Interestingly, in no instance (including the possible similar echo athwart the 1.75 NM range ring at ~350 degs on frame 775; see *Section 3*) are *Phase A* and *Phase B* echoes shown on scope at the same time. So although the echo presentations and displacements are different in the two phases, the possibility remains that all echoes are due to movements of a single target through the radar cover.

i) the Phase A echoes

As mentioned in *Section 6.a* discussing meteors, an assumption that the same single target moved at high speed from scan to scan cannot be justified simply on the basis of two possibly unrelated echoes. But in the case of 771 to 772 we can to some extent test the hypothesis against other evidence contained in the detailed echo presentation. In fact there is an elongation of both echoes in the approximate direction of the inferred velocity which could be consistent with a smearing due to rapid passage through the beam in the implied direction.

Both these echoes are roughly elliptical. See *Fig.22* below. At first glance frame 771 appears to show a roundish echo adjacent to the range ring, but close examination and contrast-enhancement bring out the brightness due to spot-integration where the "tail" of the elliptical echo overlaps the range ring (painted of course on the phosphor by the same electron beam trace). The major axis of each ellipse appears to make a roughly similar angle with a line connecting both echoes, but rotated about 10 degrees clockwise in 771 and 10 degrees anticlockwise in 772. At the same time, each of these axes is rotated with respect to a radius drawn through it from the scope centre, this time *anticlockwise* in 771 and *clockwise* in 772.

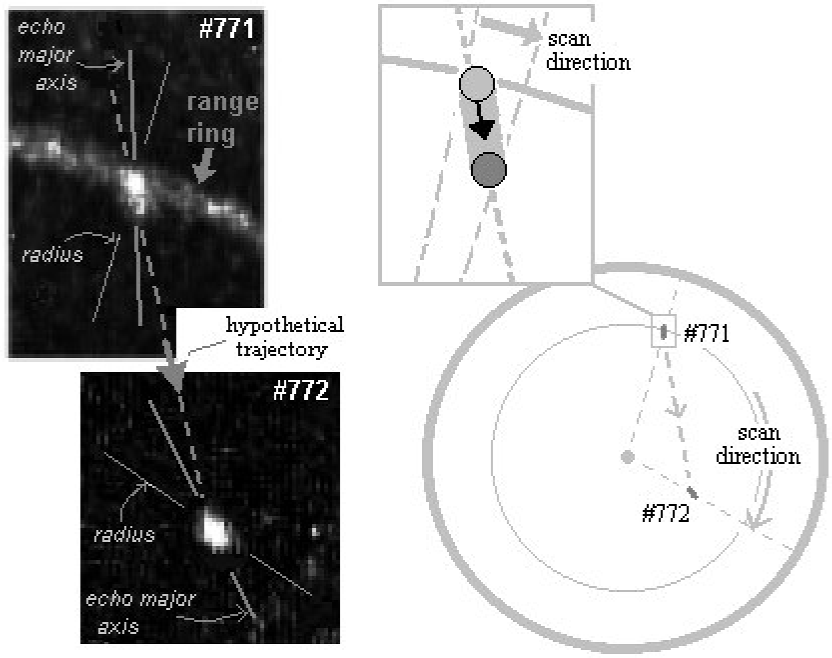

Fig.22. Echo orientation and dwell-time of a rapid target on a trajectory from #771 to #772

These angular relationships are arbitrary in relation to the scope centre and the orientation of the echoes is not that of the ordinary "target arc" indicative of a stationary or slow-moving point target. The spray of pulses returned from a point target that is stationary or slow-moving relative to the angular rate at which the beam scans past it produces a sequence of spots on the tube phosphor all at the same range over an angular width approximately equal to or less than the nominal beam width, and these spots appear integrated into a short arc of brightness lying normal to the scope radius. Echoes 771 and 772 on the other hand are orientated obliquely to the radar line of sight.

Qualitatively speaking, this could suggest targets moving through the radar cover rapidly enough to show a small range rate during their dwell-time in the beam. Moreover the directions of motion implied by the range rate in both cases - having components of velocity approaching the radar in 771 and receding from the radar in 772 - would be consistent with consecutive scans of a single target, crossing the scope on the trajectory of a line connecting the two echoes.

Quantitatively the scenario is less clear: Rotating at 120 degrees/sec the edge of the beam would be travelling at around 8000 knots at the 1.05 NM range of 772. The target displacement of roughly 2.1 miles (assuming zero degrees relative elevation) from 771-772 indicates a maximum relative average speed of nearly 1900 knots in roughly the same clockwise direction, so the target dwell-time will be extended. A 1.6-degree beam rotating at 120 deg/sec would scan past a stationary point in about 0.013 sec., but because it is overtaking a co-moving target (~100 degs in 3.8 sec is approximately 26 deg/sec) the dwell-time will be ~22% longer, = 0.015 sec. In the limit case of a co-altitudinal target averaging ~1900 knots this allows a likely range displacement of no more than a few tens of feet, only a fraction of the 123 ft theoretical electromagnetic resolution in range of a single 0.25 microsec pulse.

Two objects statically separated by this small range differential would not be resolvable in principle; however, the pulse repetition rate of 1617 pps means that during the ~0.015 second dwell time some 24 pulses are sprayed across the moving target, so it is possible that it could be detectable. The signal amplitudes of successive pulses returned from a target with a significant range rate would not add directly across the beamwidth, and the resulting integration loss would tend to reduce echo brightness slightly on the PPI. This could be consistent with the weaker presentation of echoes 771 and 772 relative to echo 773. The latter may be bright because, in part, the target is relatively stationary and does not change slant range through the beamwidth, so that the returned signal amplitudes do add on the PPI.

Nevertheless for an effective point target, i.e. much smaller than the resolution cell on both range and azimuth dimensions, the fastest relative target speed consistent with the geometry would not alone cause smearing of echoes 771 and 772 over a range differential of about 400 ft or more, as photographed, more like 1/10 of this value, so we conclude that the radar echoing area of the target had an intrinsic length in the direction of motion which was already equal to or greater than the likely resolution. In this case subtracting the relatively small motion blur would indicate the underlying physical length as "seen" by 3cm radar. This model suggests that an overall range differential in the region of ~ 400 ft, as displayed, could have been caused by a reflector whose echoing area had a true major axis of perhaps 300 ft or more (400 ft minus a motion blur component of several tens of feet) passing through the coverage on a level trajectory between the two echo positions at around 11,500 ft MSL at a true average groundspeed of ~1900 knots.

(Alternatively, the same target could be detected at a steep depression angle in the bottom of the radar cover, passing below the right wing at an altitude very much lower than the B-52. In this case the target speed could be as low as around 1000 knots. The reduction in motion blur by about 50% due to the lower speed represents a difference of probably no more than about 10% of the total echo size, so bearing in mind the likely margin of error the difference in the implied true target length is not significant. It would be several hundred feet on either scenario.)

It might be thought defensible to separate these *Phase A* echoes from the better-defined *Phase B* sequence and disregard them as of doubtful significance. After all, blips that pop up for a scan or two could be stochastic noise and it can't be proven that they have anything to do with *Phase B*. On the other hand, there is a suggestion of pattern in the tendency (one can put it no more strongly in the case of such a small sample) for these echoes to appear on scope at times when the *Phase B* echo absents itself. They are both well-defined blips with interesting structure. And finally, the point should be made that the inference we have drawn here to complete the internal consistency of a "real target" model of *Phase A* - i.e., that such a target probably has an effective length of a few hundred feet aligned in the direction of motion - turns out to be consistent also with an elongation depicted by the primary echo in *Phase B* (greater, certainly in 773, but still probably in the order of hundreds of feet), with ground-visual witness reports of a "slender" or "wiener shaped" object, and with the air-visual report of an elongated egg-shaped object (estimated >200 ft in cue-reduced dark conditions) on the ground.

It's possible then to interpret the radar sequence as showing an object stationed off the left wing of the B-52 accelerating ahead, turning around the nose of the B-52 and giving a smaller, rapidly inbound echo off the right nose on frame 771, travelling to a position aft of the right wing on 772 then back to its station on 773, then again accelerating out of the altitude hole for another two scans (or one at least; the orientation of the *possible* echo touching the 1.75 NM range ring at ~350 degs on 775 implies an inbound vector which would be consistent with the sequence) before returning a second time to its station on 776 for a final seven frames then vanishing from the radar for good.

Turning then to possible interpretations of the *Phase B* echoes:

ii) the Phase B echoes

The likelihood that these echoes indicate a compact target, narrow in azimuth, with a significant radar cross-section, at first-trip range and thus aloft inside the altitude hole, has already been argued on several grounds. But although witness and photo evidence indicate a very strong echo, we note that the echo strength indicated in frame 773 is unique in the *Phase B* sequence, and generally there is a wide variation in the presentation of the primary echo during the photography. In fact this variation is for practical purposes 100%. Neglecting deception jamming effects of the sort mentioned in *Section 6.f* (which ought not be our first resort) change in echo strength can be interpreted as:

a) variation in aspect (i.e. a relative rotation) of a single large anisotropic reflector;
b) varying augmentation by some external means of the return from a relatively small reflector of constant efficiency; or
c) varying attenuation by some external means of the return from a relatively large reflector of constant efficiency.

Or some combination of the above.

Option *c*) could include signal attenuation due to variation in range and/or variation in elevation (changing antenna gain). There is variation in displayed range over the sequence, though it is quite small, less than 20%; but it is in the wrong *direction* to account for the fact that the strongest echo occurs on frame 773 when the range is greatest. Change of target elevation is hard to rule out, but is questionable in view of the near-monotonic character of the reducing slant range and its strong correlation with the descent rate of the B-52 (see *Fig.23* below), which suggest that these two variables are causally coupled.

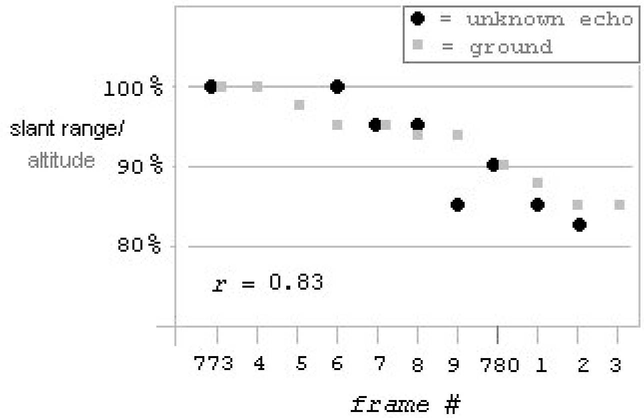

Fig.23. Correlation between rate of descent and slant range to Phase B echo

This result is consistent with a systematic relation between the rate of closure of the echo and the rate of descent of the B-52 (Note: Omission of the #775 "echo", which may or may not be an artefact, is justified on the ground that its range and azimuth are both aberrant from the coherent kinematic sequence of Phase B).

The simplest explanation of this coupling would be that during the photo sequence (though not of course during the entire event beginning near FL200) the target is maintaining constant altitude whilst pacing the descending B-52, in which case the target is below the B-52 altitude and is increasing in relative elevation. Given the known radiation pattern it would thus be moving from a region of lower antenna gain into a region of higher antenna gain at the same time as closing slant range. This is at least a natural relation, but these range and elevation changes would *both* lead us to expect a systematic increase in echo strength from 773-783. The weak trend observed, as shown in the graph of photometric values in *Fig. 24*, is in the opposite direction.

So option *a*) is also attractive. The near-radial extent of the principal echo on 773 corresponds to perhaps ~ 800 ft on the PPI, and since this would be a projection in plan of an elongated object with an unknown orientation at an unknown negative elevation, changes in attitude could presumably result in large changes in echoing area.

On the other hand, the intermittent nature of the signal changes, and the occasional presence of a fugitive secondary echo generally connected to the nearer primary echo, suggest that we also explore option *b*).

On frame 773 there is a near discontinuity between the inner primary echo and the secondary echo, though they are faintly connected by the suggestion of a narrow bridge. But on frames 776 and 781, for example, the echoes become continuous. The nearer edge appears to remain constant in position (or to follow a roughly monotonic decrease in slant range from 1.05 to 0.87 NM) whilst the outer partner is fugitive. But the outer feature does display at roughly the same *additional* slant range each time it appears. This suggests that the possibility of a direct echo from a primary reflector whose presentation is being augmented by a ghost echo from a nearby secondary reflector, reaching the antenna by a slightly longer raypath.

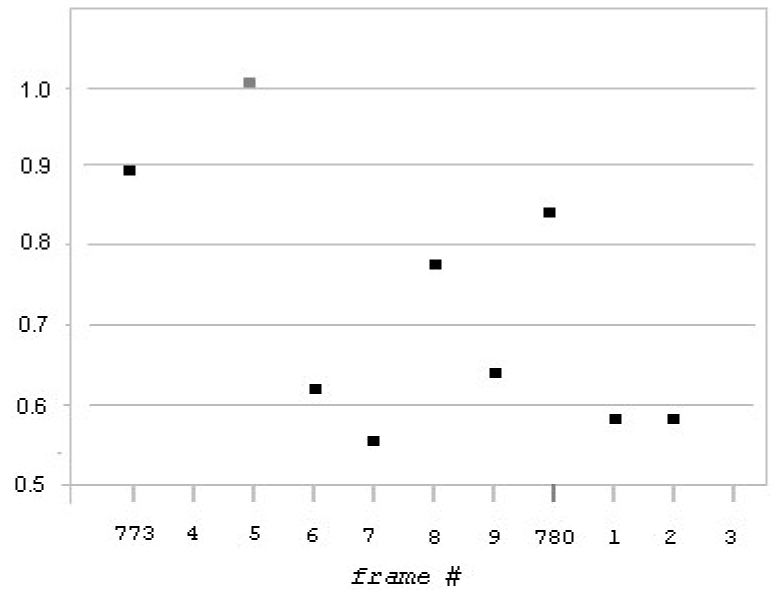

Fig.24. Fluctuation in *Phase B* echo intensity

Vertical axis shows ratio of echo brightness to that of saturated ground return on each photo.
(Echo 775 is just possibly an artefact and is shown in a lighter grey; see Section 3.)
(Photometric data courtesy of Dr. Claude Poher)

The nature of such a secondary reflector is problematic because of the small echo separation (order of perhaps 1000 ft). As described in *Section 6.l* ghosts normally arise due to an unusually efficient secondary ground reflector; and in a situation where the primary reflector and/or the radar are in motion, a persistent ghost requires a special kind of secondary reflector, a 'corner reflector' like an empty metal truck body or similar, which might be efficient over a range of changing incidence angles. But the slant range to the primary target in this case (mean approx. 5800 ft) does not allow it to be close enough to the ground. Even if we locate the primary reflector beneath the bottom edge of the main beam, close to the nadir, its altitude could not possibly be less than about 3200 ft, and realistically will be much greater. At -50 degrees its mean altitude during the photo sequence would be about 4600 ft. Moreover a remote corner reflector of any imaginable type will remain at a (more or less) fixed location relative to the aircraft, and as the range to the primary reflector from the 250 mph aircraft varies, so the separation of primary echo and ghost echo on the PPI changes in direct proportion. This would be very pronounced, yet no change in separation is detectable. These facts indicate a secondary reflector that is very close to the altitude of the primary reflector, and remains so, despite variations in efficiency, over a distance of at least a couple of miles. What could such a reflector be?

As discussed in *Section 6.k* it seems inconceivable that an undetected layer of RI discontinuity, no matter how sharp, could have a power reflection coefficient high enough to account for the primary *Phase B* echo, and the marked bearing anisotropy cannot plausibly be explained by such direct backscatter either. But it seems possible that such a layer, which would be expected to be of wide horizontal extent, might be responsible for producing a secondary ghost echo from a very efficient airborne reflector pacing the B-52 at an altitude just above the layer.

For this it is further necessary, first that the target altitude be constant relative to the layer altitude, and second that the constant difference in height can be some fraction (to depend on angle of incidence and reflection) of the constant PPI range interval between primary and ghost echoes. The first condition has the consequence that there will be a systematic relationship between the changing slant range to the primary target on the PPI and the reducing vertical distance to the layer as the B-52 descends.

Such a correlation was shown in *Fig.23*. The product moment correlation coefficient $r = 0.83$ is a very good positive correlation, though naturally short of a perfect functional relationship (the idealised relation would be a sine function) which could only occur if all measurements were precise *and* if the primary target remained directly beneath the aircraft (-90 degrees elevation) at all times. In the real case, this result indicates the likelihood of a target at a significant depression angle (else the B-52 descent would not contribute significantly to reduction of slant range) and so is not inconsistent with a target maintaining a constant altitude of around 4000 ft or more above the terrain, and therefore some significant fraction of 1000 ft (echo separation distance) above a reflecting layer at something over ~3200 ft.

The possible geometry of this situation is shown in *Fig.25*. Such a model would require that the primary target or object was at a fairly steep depression angle below the aircraft, consistent with the absence of any simultaneous aircrew visual reports, consistent with ground visual reports placing the UFO below the B-52, and consistent also with the subsequent "landing" scenario which would imply an object leaving the radar cover by dropping out of the beam.

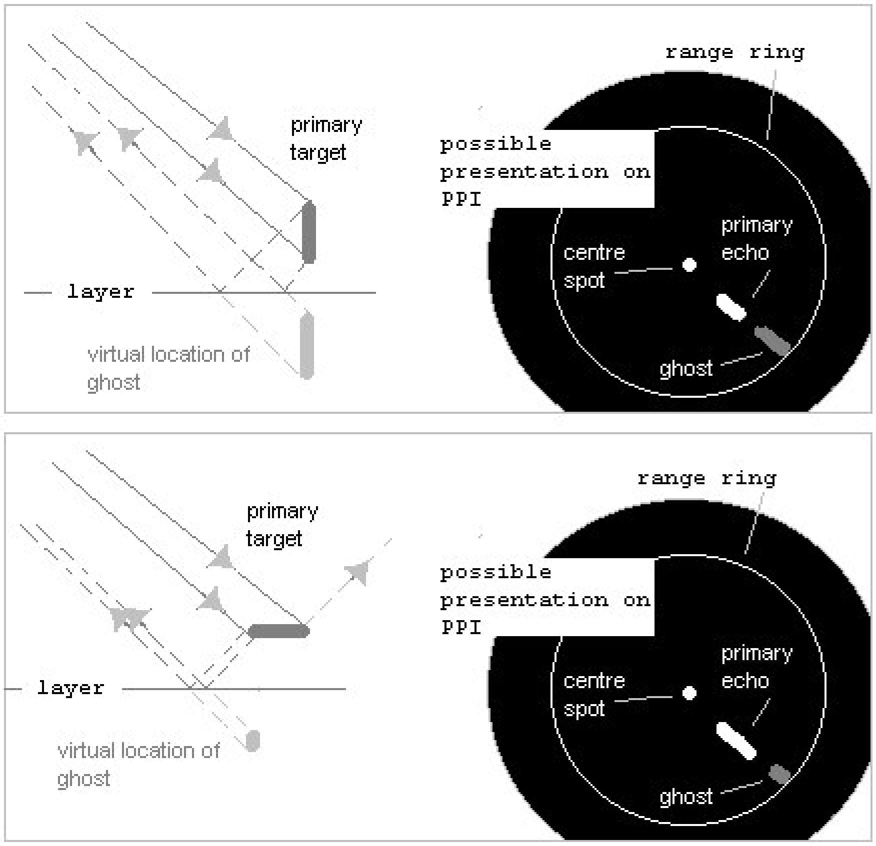

Fig.25. Schematic geometry of ghost due to scattering from layer
Small fluctuations in geometry and layer structure could cause ghost to bloom and fade and vary in extent.

Note that the conditions for producing an attenuated ghost of a large nearby target by secondary scattering from a layer below it are much less strict than would be required for direct backscatter. The geometry necessary to limit the ghost separation to about 15% of the primary echo range means that the incidence at the layer can' t be grazing, as can be seen by studying *Fig.25*, but it does not require the unrealistic normal incidence condition for the "hot-spot" direct backscatter theory either. Because this is now a *forward* scatter situation, the primary reflector is permitted to be offset from the nadir sufficiently that it can be inside the Station Keep main beam coverage, much alleviating the problem of needing an extreme power reflection efficiency from a layer.

In forward scatter the inherent layer efficiency for partial reflection is much greater than for direct backscatter at or near normal incidence, improving rapidly as the 6th power of the cosecant of the reducing angle (e.g., ratio 4.2/1 at 52 degs; 8/1 at 45 degs; 625/1 at 20 degs). In addition the radar now receives signals by multiple routes, reflected from object to layer and back, and from layer to object and back, over the same raypath.

The literature of experimental radar meteorology certainly encourages the view that very sharp laminar RI discontinuities are not only much more common than balloon soundings might indicate but may have power reflection coefficients much greater than the highest values ever directly measured. In the present case no evidence of such a sharp scattering layer was detected by radiosonde; the intriguing implication is that such a layer could not have been observed at all without the fortuitous proximity of the large unidentified primary target.

Finally there are some open questions. Col. Werlich indicates that there was no visual sighting of the object from the tower, even though a controller was following the flight of the B-52 with binoculars. Of course there is no direct evidence that the object detected on airborne radar was an optical emitter, and there was broken cloud above about 10,000 ft. But other ground observers in the area to the N and NE of the flight path did report bright lights which logic suggests may have been the same object, and the radar echo presentation seems to indicate a large body, so a tower sighting would not have been surprising. However from this vague, second-hand report it isn' t even certain that the tower controller was looking at the B-52 at a time when the object was near it.

We should also consider that no object was seen in the air from the flight deck of the B-52 even when radar showed it approaching to within about a statute mile. This might be explainable if it was at a steep depression angle out of view from the flight deck windows, and it is also true that they were flying in layers of cloud and haze during parts of the event. But there was apparently no scattered illumination of clouds or haze observed at any time. One cannot exclude the possibility of directional light emission of course (i.e, principally downward), or there may be other explanations.

Other questions involve reports of echoes on independent weather and airborne gunnery radars (see *Note 8*). The weather radar report mentioned on the RAPCON radio tapes is interesting and potentially extremely significant. Unfortunately Blue Book' s several attempts to obtain details were met with obstructive and uninformative responses from the SAC base. It seems very likely that a target of the size detected, with 1-mile to 3-mile separations from the B-52 and at altitudes generally between about 8-20,000 ft, should have been detectable and resolvable at various times by a variety of ATC and defence surveillance radars within a radius of 1-200 miles, including nearby SAGE air defence radars at Minot AFS; but if meaningful information was sought on other possible radar contacts there is no evidence of it in the file. Even information requested by FTD on the Minot AFB air traffic and weather radars, required under AFR 80-17, was not supplied. Col. Werlich only remarks that any echo on the RAPCON airfield control radar would have been obscured by the "pretty big blip" due to the B-52' s IFF transponder signal. But this is very unsatisfactory.

There are other contextual factors which are largely beyond the limited scope of this report. Two of these - the prior and coincident ground-visual sightings of unidentified lights and structured objects, and the subsequent air-visual sighting of a large structured object on or near the ground by members of the crew of the B-52 - have been mentioned briefly. Obviously the present report is not final and is only a small part of a much larger investigation.

However, the following summary is possible:

A mobile, compact, airborne target or targets of unknown nature and of large radar cross-section (order of 100m^2), flying within about 1 - 3 NM of the B-52, seems the most likely explanation of the radar echoes photographed. (Documentary evidence of independent ground radar contact with an unknown target near the B-52 does exist, but is too vague to be evaluable owing to what appear to have been constraints placed on the original investigation.) There is evidence that might be consistent with an intermittent radar ghost echo of this unknown primary target, and a hybrid model involving an efficient elevated scattering layer seems to be one possible interpretation of this, but there is no meteorological evidence for such a layer. (It is also true that the photographed structure of the echo could be related to the two-part structure of the object subsequently observed visually from the air by the pilot and copilot.)

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2) There are small uncertainties in these measurements due to inherent limitations both of the photography and of the PPI display. The geometric scope centre can be determined from the bearing ring, but the range rings show a perceptible distortion from perfect circular symmetry and are not perfectly concentric (see below). Also the print focus appears to be of variable sharpness, and/or the video gain is varied. There is also variable noise speckling in the altitude hole. Thus the rings thus have some perceptible thickness and often appear faint and broken, sometimes vanishing, which introduces uncertainty. Original range and azimuth values used were based largely on careful measurements made by Brad sparks, using the nearest parts of what were believed to be 1-mile range rings to minimise distortion effects. But further research has required revision of the PPI range scale from 1-mile rings to 0.5 mile rings, and moreover because the display trace time is triggered not at zero range but at a range corresponding to the edge of the TR (transmit/receive) hole, given as at least 2000 ft in training manual CDC 32150K, Vol.4, ranges measured from the scope centre are therefore increased by a "hidden" radius. The effective zero-point of range is 0.25 NM, such that (for example) the third, brighter, 1/2 mile range marker is actually not at 1.5 NM but at 1.75NM, as shown in *Fig.3*. Values cited are believed accurate within error bars of +/- 0.05 mi and +/-1 deg.

The cause of the display eccentricity is probably optical. The range rings are electronically produced by brightening the scope trace and may be subject to instabilities in the video voltages or changes due to local electromagnetic or geomagnetic fields; but the direction of the eccentricity, diametrically opposite to the anomalous bright patch at around 26 degrees on every photo, suggests that the distortion is due to the angle of photography and convexity of the tube face. This would be consistent with Richard Haines' identification (unpublished private report) of the bright patch as an offset ghost image of the bright centre-spot, doubly-reflected *via* the camera lens.

There is a complication, however, because the camera optics is understood to consist of a system of prisms and a lens mounted *inside* the CRT, the optical axis passing through the middle of the drive gear that rotates the tube inside its yolk to maintain "north-up" or "heading-up" presentations. (A second optical system combines an image of the clock, counter etc. onto the same film frame.) The image is therefore a reversed view of the inner, convex, phosphor-coated surface of the tube face, not of the outer, convex glass surface. Haines' theory therefore perhaps needs reinvestigation. Nevertheless the bright patch in question is almost certainly an artefact of an analogous kind.

3) As mentioned, the radarscope clock shows 0906:14 GMT at the time of frame 771, or 0406 local time. However, a transcript of the radio transmissions between RAPCON and the aircraft commander is at variance with this, indicating that the B-52 lost its UHF transmitters at 0358 local time, simultaneous with the first appearance of the radar target. Compounding this, the investigating officer' s timetable of events linked to the B-52 flight track has the aircraft some 16 miles NW of Minot at 0406 by the clock; yet the transcript of the pilot's communications with RAPCON would place the B-52 some miles SE of Minot by 0406 and perhaps already turning back on a NNW heading after executing its missed approach.

These inconsistencies at first sight suggest a possible 7-8 minute systematic error in the times recorded either in the RAPCON transcript or by the radarscope clock. The photographed clock may seem the more reliable record of the two, given that there is evidence that RAPCON transcript is at least incomplete. However clock error cannot be ruled out, since the clock is a mechanical timer which is required to be re-set by hand prior to each mission. Setting the clock accurately (to GMT) was a checklist item, but according to former B-52 navigator Richard Sessler it was nevertheless "easy to forget" and he admits to doing so himself on occasion.

The possibility that the clock may run inaccurately has been considered. An inquiry by Jim Klotz to the manufacturing company, Bulova, disclosed that typical variation acceptable in a comparable instrument watch might have been in the region of +/- 1/2 minute over 3 days, and that a variation of 7-8 minutes in 10 hours (the duration of the mission) would indicate a mechanism in bad need of an overhaul. Although this has to be considered less likely than a setting error, as mentioned above the photos do indicate a small discrepancy between a scan/photo rate of 3 seconds and the clock time of around 0.5 - 1.0 second over 36 seconds which, multiplied out over 10 hours, would accumulate to approximately 8 minutes. In other words the clock is "slow" relative to the nominal 20 RPM radar scan rate, which, if the latter could be relied upon, might be explained by inadequate winding or a weak spring, for example.

However the discrepancy from the indicated Control Tower time is in the other direction, and would require the clock to be *fast*, not slow. So this phantom 8 mins appears to be a coincidence. The small photo discrepancy is probably due to imprecision in the radar antenna's hydraulic motor and/or rotation control mechanism (the ASB-4/9 Tech Order gives the nominal 20 RPM setting as "17.5 - 22.5 RPM") and there is no internal evidence in the photos that the clock is not accurate.

4) Blue Book documents and maps indicate that Werlich located the photo position at the end of the radar event at least partly on the basis of contemporary crew testimony to the effect that the camera was not switched on until the end. McCaslin confirms Werlich's contemporary report. This is also consistent with psychological and operational factors. When the UFO first appeared the B-52 was already heading home at this point, there were no bomb-nav exercises in prospect and all that remained to complete the Instructor pilot's Standards & Evaluation exercise was the approach to Minot. When reports were received from RAPCON of a UFO in the area, McCaslin asked Ritchie to switch the radar into Station Keep mode. It was not uncommon to do this during an approach, but camera operation is not automatic and has to be manually selected. No-one thought of the camera until the pilot suggested it near the end of the event.

5) An STC filter (not to be confused with Sensitivity/Time Control) is also sometimes known as Fast Time Constant, or FTC, a name more descriptive of its function: It is a circuit in the video amplifier whose purpose is to suppress echoes on the display in inverse proportion to the rate of rise of the input signal, or in other words to the steepness or sharpness of the leading edge of the envelope. The effect if used in a terrain mapping radar mode would be to eliminate or reduce the intensity of echoes with slower rise and decay times which return from gently varying terrain, whilst preserving sharper echoes from features like buildings, riverbanks or coastlines.

6) Power reflection coefficients at normal incidence in excess of 10^-14 or -140db attenuation are thought possible on occasion (Atlas 1959), so given a peak power in the order of 100 kW then for a spillover lobe 30db down on the main lobe this gives about 10^-17 of 100 kW or 10^-12W, which is about the power commonly reckoned to be in one Just Detectable Echo or a faint blip at the limit of detectability on a typical PPI. Evidently much higher efficiency than one JDE would be indicated in this case, given expert testimony of an echo significantly stronger than that from a very large jet at close range. Since the ratio of normal signal intensities on a PPI might easily range up to 10^4 (a single aircraft at constant range could vary by as much as 10^3 depending on aspect) we should probably assume an echo of at least 10^4 or 10^5 JDE.

7) The UHF frequency in question was around 270 MHz. Given dark sky conditions one would have to assume a considerable depth of weakly-ionised air in the line of sight in order to achieve a significant radio opacity at the same time as zero effective optical emission from recombination. It seems conceivable that a certain critical electron density might create a "one way" radio mirror, *if* the aircraft UHF transmissions were of lower power than the ground UHF transmissions, explaining the loss of all transmissions from the aircraft to RAPCON during the incident whilst the aircraft could receive RAPCON transmissions perfectly. There is presently no information on radio power outputs however.

The main problem with this model would then be how to account for the origin of a large volume of ionised air in the absence of any atmospheric electrical activity. It would be reasonable to speculate that this could be related to the presence of the unidentified radar target and associated visual reports of a luminous object or objects; but as already discussed there is presently no available physical model of such a phenomenon. Also the ionisation theory does not explain in a very natural way why the UHF transmission cut out suddenly in the "middle of a word", implying a very rapid rise in the electron density along the radio line of sight some 90 degrees of azimuth and some 6000 ft away from the presumptive source. It would be interesting to investigate the decibel attenuation required for signal strength to go from receiver saturation to receiver noise level. Some estimate of the rate of rise of electron density in the line of sight could then be derived, leading possibly to limits on ionising particle energies and an overall mean power output.

Such speculation aside, this model is fairly consistent with the report. Short waves are less subject to scatter from ionisation than are long. This dependency has been measured as proportional to the cube of the wavelength for electron densities typical of meteor trail ionisation, ~10^12 cm^-3, and proportional to the power 7.7 of wavelength for auroral ionisation with electron densities around 10^5 or 10^6cm^-3. It is reasonable to assume that densities in the present case would be lower still and the wavelength dependency of a higher power than 7.7. This fits the sequence of events in the RAPCON transcript: Ground reception of the B-52 was initially weak on 271.3 MHz but immediately loud and clear when they switched to 326.2 MHz. Conservatively assuming a power 7.7 wavelength dependency, ionisation would be more transparent by a factor of about 4.0 or better at the higher frequency. Meanwhile the B-52' s IFF signal and raw radar paint (probably nearer 3 GHz) were both apparently detected without difficulty on the ground; and the B-52' s radar also continued to paint a constant ground echo at 3cm (10 GHz), because attenuation at these wavelengths would be in the order of 10^10 less than at one metre and therefore negligible.

If the asymmetry between the two radio responses remains too much of a problem to be explained by a power differential and a "one-way radio mirror", one other possibility that might be investigated is icing-up of the UHF transmitter power relay. Unlike some other types of relay failure this could be spontaneously self-correcting. Radiosonde temperature readings given in the file (for Glasgow, Mont., *Table 4*) show 1.0 degree C above freezing at the highest level recorded, 11,500 ft above terrain. Subfreezing temperatures are very likely at higher levels of the B-52 approach. However one would have to demonstrate the unusual vulnerability of this crucial power relay to icing (unlikely given the sealed components used at this date); explain why no other systems on the plane appear to have been affected; and explain the fact that the relay had been operating perfectly normally for some time at FL200 and higher, and would be expected to be warm, which seems inconsistent with sudden freezing in the middle of a transmission just when the B-52 started descent. In summary, there seems to be no wholly satisfactory explanation of the UHF failure.

However Claude Poher has proposed a very interesting hypothesis to explain the asymmetry of this situation. He proposes that a region of weak air ionisation is associated with the presence of the unidentified object, just below a threshold electron density at which it would begin to noticeably affect UHF transmission and reception. However each time the copilot depresses his transmit switch to energise the radio transmitter the electric field strength around the antenna is increased and free electrons are shunted along the field lines. Obviously the energy used in this redistribution of charge is energy stolen from the transmitter power, so the output radio signal is effectively ' shorted' . It' s possible that this could neatly explain why only air-to-ground UHF transmissions were affected.

8) The RAPCON tape transcript contains the following message to the B-52 timed at 0852 CDT by the tower clock (03:52Z): "The UFO is being picked up by the weathers radar also, should be at your 1:00 position 3 mile now." The aircraft responded that they "do not have anything on airborne radar and we are in some pretty thick haze right now and unable to see out that way." The time of this message would be before the 30/180 turn onto the TACAN initial approach fix and so prior to the start of the ASB-9 radar episode discussed here. The file shows that Lt.Marano from FTD made several attempts to get further information from Col.Werlich about the weather radar but was either rebuffed or ignored. It has not proved possible to find information about the characteristics or location of the weather radar involved. Generally one would expect this sort of radar to operate at X-band (similar to the 3 cm airborne radar) or S-band (up to 10 cm). Weather radar is by no means generically inferior to other types of radar, requiring good accuracy and resolution, and most importantly radar height indication as well.

Another puzzle is a report of a rapid unidentified echo on the B-52 gunnery radar. According to the gunner, at some point during the ASB-9 radar episode a target was picked up on the scope of the rearward facing AN/ASG-1gun control radar. It was aft of the aircraft 30 degrees to port of the centre-line (i.e., at about 7 o' clock, behind the left wing) and moved from 1000 to 12,000 yards range in a few seconds (less than 10). It was a "brilliant target". The gunner was impressed by its size and speed, and noted that there was no clutter or other echoes on the scope. Little information is available presently about this radar, but it appears to have been a multilobe tracking radar employing sum-and-difference circuits for ranging and and target following. Probable wavelength would be under 3cm. Azimuth coverage was 320 degrees, 160 degrees left and right of the tail. But there is no reference at all to this incident in the official file and other witnesses have no memory of it..

There is also uncertainty about the role of ground radars in addition to the weather radar. Col. Werlich states that RAPCON at Minot AFB did *not* detect the UFO at any time, but he observes that "IFF equipment was operating in the airplane. It's a fairly good size blip. Every time it sweeps it shows the blip. The object would have been covered by the blip." It is unclear whether he is referring to the surveillance radar or the precision approach GCA radar or both. The ADC radar south of Minot "do not remember" seeing any unidentified targets says Werlich, but this is a fairly meaningless statement. FTD' s requests for more information on this, and on the RAPCON radars, were no more successful than their requests for details of the weather radar report. Werlich' s only response is the inaccurate reassertion that only the B-52 bomb-nav radar was involved. This is very unsatisfactory. Werlich himself indicates that he was denied the technical assistance he requested from SAC to further his investigation, and in the context of SAC' s sensitivity about some security implications of the incident this is certainly suspicious.

It has been possible to find the following information on radars operational the the Air Defence Command SAGE [Semi Automated Ground Environment] radar site 16 miles S of Minot in October 1968:

FPS-26 Height Finder
2 x 2.5Mw
pw 4.5µS
pps 333-328?
5.4-5.9GHz
Made by AVCO. Dual Channel at 2.5 Mw each or one channel at 5Mw. SAC 42A Klystron. 3000-3045 PRT.

FPS-26A Height Finder
2 x 2.5Mw
pw 4.5µS
pps 333-328?
5.4-5.9GHz
Made by AVCO. Said to be similar to FPS-26 except 3000-3048 PRT, and extra ECCM features.

FPS-27 Air Surveillance
15Mw
pw 6µS
pps 333
2322- 2670 MHz
Made by Westinghouse. tacked beam system using 10 vertical beams.

Note the "diversity operation" of the heightfinders - two transmitters of 2.5MW each are operated in tandem with the pulse repetition rate slightly out of phase and the delayed signals recombined at the receiver to give an effective 5MW peak power.

All these radars were also part of the ADC "Frequency Diversity Radar Program". Frequency diversity means that as well as being slightly delayed, multiple channels are assigned slightly different frequencies - usually about 5% or less - which increases probability of detection by receiving different scattering patterns from a single target. The SNR increases like the square root of the number of channels and the practical range performance similarly. Whether this freq diversity applies to all 10 of the surveillance beams isn' t certain. The vertical stack probably also gives the FPS-27 a heightfinding capability as well.

Note that the range dimension of the resolution cell, in the surveillance set in particular, is quite poor at 6 microsec., about 0.5NM (0.38NM for the heightfinders). No information is available on beam width. The surveillance peak power of 15MWatt converts to a mean power of 30kW, so this is a powerful transmitter designed for long range. The unambiguous range allowed by the interpulse time would be about 240NM.

9) For completeness we should note that rocket missiles conceivably could exhibit these rates, and the area was dotted with Minuteman ICBM silos. But it is hard to think of a reason why missiles would be in flight in this area at this time - barring accident or mischief with potential consequences so serious that one can scarcely imagine the cause remaining undiscovered - and of course the extended *Phase B* episode does not remotely suggest a missile. None of the witness testimony on file is remotely consistent with missile launches or impacts.

10) Complete NCDC rawinsonde dataset for 0000 hrs and 1200 hrs, Oct 24 1968, Bismark, ND:

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000240114646N10045W19681024000010999909000+01071-01709633300700000003
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