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Atmosphere or UFO? A Response to the 1997 SSE Review Panel Report

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Abstract — Radar and radar-visual sightings were among the various types of UFO sightings discussed by the review panel sponsored by the Society for Scientific Exploration in the Fall of 1997. Although several well-described cases involving radar were presented to the panel, including cases in which apparently structured objects were seen coincident with radar detection, the opinion of the panel was that, whereas a few of the cases might represent "rare but significant phenomena," "rare cases of radar ducting," or "secret military activities," none of the cases represented "unknown physical processes or pointed to the involvement of an extraterrestrial intelligence." One of the panel members (Eshleman) proposed a general explanation for the radar cases in terms of atmospheric effects including refraction and ducting. There is no indication in the complete report that the panel members offered specific explanations for any report, or that any panel member was able to prove that atmospheric effects of any sort could account for the radar and radar-visual sightings. This paper, a response to the panel opinion, demonstrates that careful consideration of atmospheric effects is not sufficient to explain at least some of the radar, radar-visual, and photographic sightings that have been reported over the years.

Keywords: UFO — radar — visual — sighting — New Zealand — Switzerland

Introduction

At the October 1997 workshop sponsored by the Society for Scientific Exploration, Jean-Jacques Velasco and Illobrand von Ludwiger presented to a review panel a number reports on "anomalous radar targets," or radar UFOs, as well as a few cases in which objects were seen at the same time that radar detected an unidentified object (radar-visual UFOs) (Sturrock, 1998). Velasco presented an excellent example of the radar-visual category in which an object was seen above clouds (altitude about 10 km) by an air crew flying at an altitude of about 11,700 m. The object, with the shape of a "gigantic disc" estimated to be 1 km wide, was "positively detected" by radar, according to Velasco, for a period of 50 s moving at a speed of 110 kts, then 84 kts, and then zero before it disappeared visually and on radar without apparent motion. According to Velasco there appeared to be "good correspondence between the radar measurements and the visual observations." Velasco stated that the French

National Space Agency sponsored research group "Service d'Expertise des Phenomenes de Rentrees Atmospheriques" (SEPRA) had studied about a hundred such cases. Von Ludwiger discussed radar cases from Switzerland, including a radar-multiple witness visual sighting that occurred in June 1995, in the afternoon. According to von Ludwiger, "Six employees, including radar operators, of the military ATC (Air Traffic Control) at Dubendorf, Switzerland, observed from their building in Klothen a large silvery disk apparently at a distance of 1700 m. It appeared to be rotating and wobbling at an altitude of 1300–2000 m. There was a corresponding recording of a target by three radar devices." Von Ludwiger also referred to several cases of "radar only" sightings of objects which followed "anomalous trajectories." One of these cases is discussed more fully below. Also discussed is a series of sightings in New Zealand which were not presented at the workshop.

The summary report of the panel (Sturrock, 1998) essentially ignores the radar-visual evidence, referring only to "a few reported incidents which might have involved rare but significant phenomena such as electrical activity high above thunderstorms (*e.g.,* sprites) or rare cases of radar ducting." The report continues, "...the review panel was not convinced that any of the evidence involved currently unknown physical processes or pointed to the involvement of an extraterrestrial intelligence." Furthermore, echoing Edward Condon's conclusion (Condon & Gillmor, 1969) written in 1968 ("nothing has come from the study of UFOs in the past 21 years that has added to scientific knowledge" and "further extensive study of UFOs probably cannot be justified in the expectation that science will be advanced thereby"), the panel concluded that "further analysis of the evidence presented at the workshop is unlikely to elucidate the cause or causes of the reports" which were presented, although "there always exists the possibility that investigation of an unexplained phenomenon may lead to an advance in scientific knowledge" in the future. Although not stated explicitly, one implication of the panel conclusion is that further analysis of old cases probably would not be fruitful. (I should point out that the panel reached this conclusion after reviewing not only radar and radar-visual evidence but also photographic evidence, evidence of vehicle interference, physiological effects on witnesses, injuries to vegetation, analysis of debris, and marks on the ground.)

Further analysis of an old sighting may not positively identify the cause, but it may show that there is no conventional explanation. If there is enough information available to rule out all known causes, then it is legitimate to claim that the sighting is evidence for some new phenomenon, something not yet comprehended by scientists. Unfortunately, the panel did not pursue the investigation of any of the cases far enough to determine whether or not there were some cases that could not be explained as conventional phenomena. This paper demonstrates that the careful analysis of old cases can provide evidence of unexplained phenomena, and therefore could advance scientific knowledge. The cases considered in this paper are classified as radar, radar-visual, and photographic.

Radar UFOs of Atmospheric Origin

In commenting on radar detections of unidentified objects or phenomena, Von R. Eshleman, in Appendix 4 to the report (Sturrock, 1998), wrote, "It is possible that some of the radar cases presented to the panel have a natural explanation," leaving open the possibility that some do not have a natural explanation (but Eshleman did not pursue this possibly fruitful avenue of investigation). Specifically he suggested that "time-variable atmospheric ducting" of electromagnetic radiation could explain some of the radar sightings. He pointed out that atmospheric effects can make it appear to the radar that there is a target (a reflector of radiation) where there is, in fact, no target. In particular, ducting or bending of the radiation by the atmosphere can make it appear to the radar set that a reflective object, a radar target, is at a higher altitude than it really is.

According to Eshleman, "...some of the echoes obtained by military radars... are based on measured time delays and measured elevation angles-of-arrival of the reflected energy from the echoing object. As presented, certain target positions were plotted as height *vs.* time. But height is computed from two parameters: (1) the measured time delay, which is a very good indication of range; and (2) the measured vertical angle of arrival, which may not be a valid representation of the vertical direction to the target." The measured vertical angle of arrival will not actually be the straight line direction to the target because refraction in the atmosphere bends radiation downward as it travels from the radar set to the target and then back to the radar set. The bent ray path forms an arc (convex upward) above the earth's surface. When ducting occurs, the arc is sufficiently curved so that rays emitted horizontally or upward at a very small elevation angle, which would ordinarily not reach earth's surface, are bent downward far enough to illuminate objects that ordinarily would be below the radar beam, such as ground targets and low-flying aircraft. The echo returns along the same path as the transmitted ray and therefore the echo radiation is traveling horizontally or slightly downward when it reaches the antenna. The radar system interprets this as the echo from an object above the ground. More specifically, Eshleman wrote, "...when ducting occurs reflections from distant and distinct surface targets (buildings, bridges, trucks, *etc.*) may be received at elevation angles of several degrees so that a ground target at a range of 100 km, for example, could appear to represent an object at a height of several kilometers." If the duct — which is a weather-based phenomenon — should change suddenly, the radar target could appear to move upward or downward depending upon whether the curvature of the arc should happen to increase or decrease. According to Eshleman, "Atmospheric turbulence would distort the duct and cause sudden changes in angle of perhaps a few tenths of a degree, which could be interpreted as a sudden change in altitude of the order of half a kilometer" for a target 100 km from the radar station.

If a duct were created where there had been no ducting, a radar target might suddenly appear. Conversely, if the ducting suddenly became much weaker or ceased entirely, the radar target would vanish. Thus Eshleman's discussion shows how atmospheric refraction could "create and annihilate" unidentified targets above ground that really are not there and how changes in the atmosphere could make those targets seem to move up and down. Although lateral bending of radiation is much smaller than vertical bending, Eshleman points out that "The horizontal angle of arrival would also be affected by turbulence, adding to the chaotic character of the apparent flight path." However, this lateral bending would be very small (hundredths of a degree) and might not even be detected by a typical search radar.

If a duct were to cause the radar to illuminate an object that was moving laterally on the ground (truck, train, *etc.*) or above the ground but normally below the radar beam (aircraft, balloon, *etc.*), then the radar would display a moving target at some altitude where there was, in fact, no target. If, also, there were variations in vertical refractive beam bending, the target might appear to the radar as if it were changing altitude as it moved along. Under some unique atmospheric circumstances it might appear to the radar system that this target was moving along a straight slanted path, either upward or downward.

Although Eshleman discussed the possibility that atmospheric refraction could explain some unidentified radar targets (radar UFOs), he did not pursue this explanation to its logical conclusion by demonstrating that it would explain any specific case presented at the workshop. Presented below is the analysis of one of the more surprising radar tracks presented by von Ludwiger at the workshop. The analysis demonstrates that atmospheric refraction could not account for the height of the target. Nor could it account for the speed or linear path of the target. Then this paper presents the history and analysis of a series of unexplained sightings that occurred off the coast of New Zealand in December 1978 (sightings which were not presented for discussion at the workshop), and demonstrates that atmospheric phenomena could not account for them.

Linear Track, Mach 3

On March 8, 1995, a military radar station near Lucern, Switzerland, detected a series of anomalous radar "targets," or "hits," which, taken together, appear to make a consistent track of an unidentified object (Figure 1). This was one of dozens of targets, some unidentified, that were detected by the Swiss military and civilian air traffic control network on that day. What made this track particularly interesting is that, in three-dimensional space, it was nearly a straight line descending from about 21.7 km to about 6.2 km (according to the radar system), while extending horizontally a distance of about 240 km. The

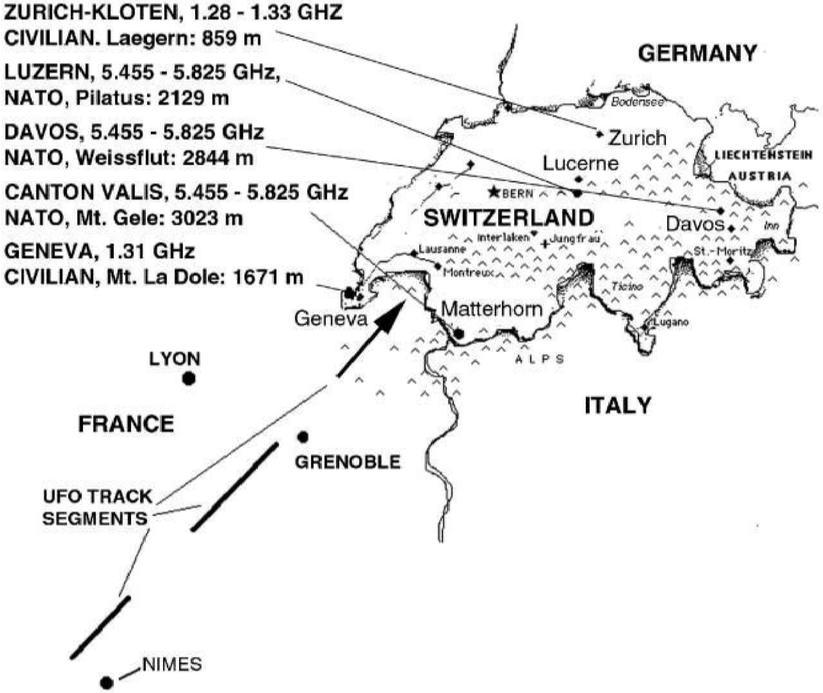

Fig. 1. Geography of the supersonic flight of March 8, 1995.

speed was nearly Mach 3, whereas Mach 2 is the upper limit of speed for high performance aircraft in European air space (von Ludwiger, 1998).

The first detection occurred when the target was about 430 km from the radar station. The radar system, which measures height and azimuth, calculated an altitude of about 21.7 km. Since the radar station is at an altitude of about 2.1 km, the elevation angle of the target was roughly equal to arctan([21.7–2.1]/430) = 2.90°. The radar station recorded four "radar hits" at 10 s intervals (6 rpm beam rotation rate) which make up the first segment. Then the system no longer registered this object. During this 30 s period of registration, the object decreased in altitude by 1.9 km from 21.7 to 19.8 km altitude (Figure 2). It also traveled about 28 km to a point about 402 km from the station (Figure 3). At the end of the track, the angular elevation was roughly equal to arctan ([19.8–2.1]/402) = 2.80°. The downward slope of the track was about arctan (1.9/28) = 4.3°. The track length was traversed in 30 s so the average speed was about 3360 km/h. The military radar has the capability of measuring the radial (toward or away from the radar) component of the instantaneous velocity by measuring the frequency (Doppler) shift of the returned radiation. The radar measured velocities of 3348, 3358, 3356, and 3368 km/h at the four detections

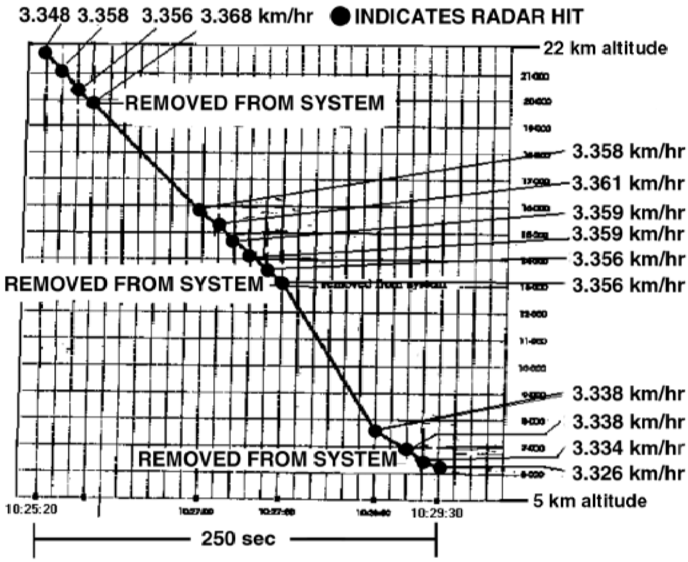

Fig. 2. Altitude graph of supersonic flight, March 8, 1995.

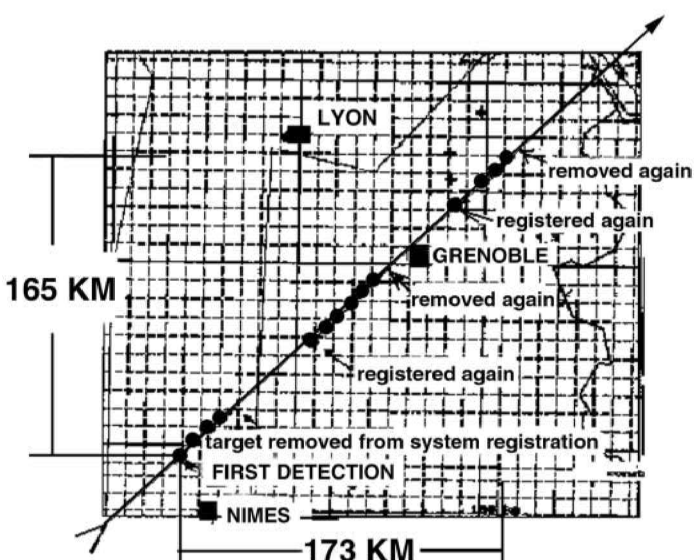

Fig. 3. Ground track of the supersonic flight of March 8, 1995.

(see Figure 2). These are about 90% of Mach 3 (about 3700 km/h). Since these speeds were measured along a track that deviated by only 4° from being directly toward the radar station the actual velocities were about 0.2% larger than the measured values (1/cos(4) = 1.002).

The radar system has operating "rules" or protocols which determine which objects are to be continually tracked or registered on the display and which are to be ignored. After a few detections the system automatically rejects objects that are above some altitude, that travel faster than some speed, that change direction often (erratic) or that have some other characteristics (some classified). The system dropped the track of this object from its registry of targets after the fourth recorded position. Exactly why the system dropped this target cannot now be determined. However, it probably dropped the target because its speed and altitude put it out of the range of ordinary aircraft. (During the cold war period it might have been tracked continually to be certain it was not some type of missile coming toward Switzerland from a high altitude.)

No more hits were recorded for 70 s. Then, the Lucern radar and another military radar station independently detected what the system interpreted as being a "new" object at a distance of about 335 km from the Lucern station. Each radar recorded a track during six rotations. The tracks did not coincide exactly. This does not mean that there were two objects traveling side-by-side, but rather that the two radar stations had not been properly synchronized to guarantee that the two radars would show exactly the same location of an object in this particular geographical area. The two tracks, although parallel and exactly the same length, were separated laterally by a few kilometers. Only one of the tracks is shown in Figures 1 and 3. (Note: The detection by a second radar station rules out the possibility that this track was caused by an electronic malfunction of the Lucern radar.)

This time the system recorded six consecutive returns, each registering a radial speed component of about 3360 km/h. The direction to the radar station was now about 6° to the right of the direction of travel, so the actual velocities were about 0.4% larger than the measured values. During this 50 s period, the altitude decreased from about 15.7 to about 13.1 km and it traveled about 47 km along a straight line, with a downward slope of about 3.5°, at an average speed of about 3380 km/h. The angular elevation decreased from about 2.6° to about 2.4°. The radar system map (Figure 3) shows that this second track aligned perfectly with the first, with a gap between the segments of about 67 km length. The altitude at the start of the second track segment is consistent with the rate of decrease of altitude as projected downward from the first track segment, although the slope of the second track segment is slightly less (3.5° *vs.* 4.3°; Figure 2).

Again the system dropped the track. A minute later the Lucern radar began to record hits on yet another "new" object, now at about 228 km from the radar station. This time the object was detected, lost and then detected three more times, over a total of 40 s before it was dropped for third and final time at a distance of about 190 km from the radar station. The radar indicated that the altitude decreased from about 7.7 km to about 6.2 km while the object traveled a horizontal distance of about 38 km. The track had a downward slope of about 2.5°, an average velocity of about 3400 km/h, and instantaneous radial velocities ranging from 3338 to 3326 km/h. The angle between the velocity vector and the direction to the radar station was about 12°, so the actual instantaneous velocities were about 2% larger than the Doppler velocities, *i.e.*, they ranged from 3392 to 3404 km/h, consistent with the average velocity. This third track segment started at a distance of about 60 km from the end of the previous and it had the same direction as the previous two tracks (Figures 1 and 3). The angular elevation started at about 1.6° and decreased to about 1.4°. The graph of altitude *vs.* time shows that the last altitude values lie somewhat below the linear projection of the altitude value from the previous two track segments (Figure 2).

The consistency in velocity and direction of the three track segments strongly suggests that what was detected was a single object that traveled about 240 km during a time period of 250 s, which corresponds to an overall average velocity of about 0.96 km/s or about 3456 km/h. If, on the other hand, these tracks are assumed to have been made by three objects at different altitudes and different distances, then the correlation in direction of travel, rate of descent, and velocity must be considered remarkable, and the question must be asked: why were all three detected not at the same time?

Assuming the tracks are due to a single object, then its velocity during the time between the first two track segments was about 3446 km/h (67 km in 70 s) and during the time between the second and third segments its velocity was about 3600 km/h (60 km in 60 s). These velocities are several percent higher than the velocities measured during the track segments. This object also decreased in altitude from 21.7 to 13.1 km during the 150 s between the first detection of the first track segment and the last detection of the second track segment at an average rate of about 57 m/s. Then its altitude decreased from 13.1 to about 7.7 km over the 60 s between segments 2 and 3 (see Figure 2), which corresponds to an increased descent rate of 90 m/s. Its final descent rate was about 37 m/s. This suggests that the object could have been "leveling off" after a rapid descent. At the end of the track it was traveling at Mach 2.75, considerably above the maximum allowed flight speed in Europe, at an altitude of only 6.2 km.

The detections of this object raise a number of questions, which, unfortunately, cannot now be answered: (a) why did the system not record the object before the first recording (Was it too high? Was it too small for detection at more distant ranges?), (b) was it detected, although not presented on the radar scope, during the gaps in the record, and (c) why did it never pick up the target again after the last recorded position? (Did it decrease in altitude and travel below the beam? Did the object turn onto a very different track and disappear in the Swiss Alps?)

A straightforward explanation would be that the radar detected a military jet traveling considerably above the European "speed limit." This would have been an aircraft with its transponder turned off, since there was no "secondary radar" return which would have positively identified it. The speed is beyond that which is allowed over Europe. If this was not a jet aircraft, then one must appeal to conventional radar anomalies or malfunctions to explain the track before suggesting more exotic explanations. Therefore let us follow Eshleman's suggestion and investigate the possibility that atmospheric refraction could explain this anomalous target.

Each section of this radar track has two main characteristics, the lateral speed and decrease in altitude. The question to be answered is, can atmospheric refraction effects explain these characteristics? Following Eshleman's suggestion that variations in the amount of atmospheric refraction could fool the radar system into reporting a change in altitude of some distant object, one can calculate atmosphere-caused altitude changes at the various distances along the track and find out if they are commensurate with the values actually calculated by the radar system. The change in calculated altitude, dH, at range R, is given by $dH = R\ de$, where de is angle variation in radians as measured by the radar system. A tenth of a degree is 0.00174 radians. Therefore, a tenth of a degree angle variation at the distance of the initial track, about 430 km, corresponds to a height variation of $dH = R\ de = 430\ (0.00174) = 0.75$ km. (Atmospheric refraction would have only a slight effect on a differential calculation.)

According to Eshleman, angle fluctuations of several tenths of a degree could occur as turbulence distorts a radar duct. Thus one might expect the calculated altitude to vary by 2–3 km at 430 km. The actual calculated height difference is the difference between the initial and final heights given by the radar, 21.7–19.8 = 1.9 km. Thus the effects of atmospheric refraction and turbulence might explain the variations in the calculated height. However, atmospheric refraction cannot explain the calculated height itself, 21.7 km, at the start of the track. That is, one cannot assume that the radar station detected a moving object at or just above the ground level and that the atmosphere bent the ray path sufficiently to make it appear to the radar that the elevation was 21.7 km. In order to calculate this altitude, the radar system measured some angle of arrival and then used a standard technique based on a "model atmosphere" to account for (correct for) the effects of atmospheric refraction.

Because the ray paths are curved (convex upward), the actual angle of arrival of the echo from the object was larger by some small amount than the "straight line propagation" angle, 2.9°, given by radar range and estimated altitude. If the actual atmospheric conditions were somewhat different from those built into the "model atmosphere" calculation, then the straight line propagation angle could be off by a small fraction of a degree. Hence the radar calculation may have been in error by a few hundred meters to a kilometer or so in altitude, but no more. Even under trapping conditions (which were not occurring at the time), the altitude of a target at an angular elevation of a few degrees will be reasonably well calculated. Hence the object had to have been far above the altitude of the radar and at or close to 21.7 km. The same argument holds for the other track segments: atmospheric refraction cannot account for the altitude so the object must have been at a considerable altitude above the ground during each of the segments.

Although variations in atmospheric refraction might explain variations in the calculated height of a high-altitude object, the probability is low to zero that random fluctuations in the refraction would make it appear that the altitude was decreasing in a uniform manner during a track segment 30 s long or longer. Moreover, it is almost unimaginable that such random fluctuations would create the appearance of altitude decreases that were correlated from one segment to the next. Hence one may conclude that atmospheric refraction played no more than a minor role in determining the calculated altitudes of this object.

Atmospheric refraction effects cannot explain the horizontal component of the distance traveled during any of the track segments. To understand why this is so, it is necessary to imagine some way in which the radar path distance could change with time to give the impression of a moving target even if the reflecting object were stationary. Imagine that refraction bends some radar radiation downward so that it reflects from a ground level object. At the time that the initial echo is registered by the radar system the distance over the curved path is some value. Then the curvature of the path changes, thereby changing the overall path length (the radar distance). It will appear to the radar that the target moved. (Note: a radar antenna emits a beam with a vertical distribution of radiation (a "fan" beam), so there is always radar radiation available over a vertical range of angles that could follow any curved path to a particular object. Therefore, as the curvature changes, different portions of the radar beam may reflect from the target.) If the curvature changes quickly, the radar target will appear to move quickly either toward or away from the radar set depending upon whether the curvature decreases or increases. Hence one might consider this to be a mechanism for explaining moving "radar UFOs."

However, this mechanism will not work because the curvatures are much too small. Consider that for a ray with a curvature equal to that of the earth (radius of curvature = 1/(6330 km) = 0.000158 radians/km), that is, a ray which has been trapped by a higher than normal amount of refraction, the curved path distance between points with a straight-line separation of 430 km is 430.08 km. If this ray were to suddenly "straighten out," the radar would indicate a decrease in distance, but the decrease would only be about 80 m. In most cases the radius of curvature of a ray path is greater than that of the earth, but even in the "super-refractive" conditions when the radius of curvature is slightly less than that of the earth, the curved path length does not differ by more than a hundred meters or so from the straight-line path. Hence it should be apparent that one cannot attribute sizable radar range changes to variations in the path curvature caused by variations in atmospheric refraction. Since atmospheric refraction cannot explain the track length it also cannot explain the horizontal component of speed. Hence one must reject explanations such as anomalous detection of a building or a mountain top or a moving ground vehicle. Even detection of a high-speed aircraft at low altitude must be ruled out for the first two track segments.

Having exhausted the possibilities for explaining this track as resulting from ray bending due to atmospheric refraction, the only remaining conventional explanations to consider are “radar angels” ... unidentified targets within the atmosphere that could be anything from birds and insects to “clear air turbulence” (CAT) and related atmospheric inhomogeneities. However, all of these targets are very weak reflectors of radiation which would have been undetectable at these distances and they do not move rapidly or consistently over long distances (Skolnik, 1970, 1980).

Since atmospheric phenomena and angels cannot explain the high-speed 240 km long track, the only remaining conventional possibility is that originally proposed: a high performance aircraft was breaking the speed rule as it flew almost directly toward the radar station. However, even this is questionable because the cross-section of a high-speed jet viewed head-on might be 2 m^2 (two square meters) or less, which is considerably below the estimated minimum cross-section for radar detection at 430 km, that is, 6 m^2. (The sensitivity of the radar is rated at roughly 10 m^2 at 500 km. Considering the inverse fourth power detection equation (Condon & Gillmor, 1969), with all other quantities being constant, detection at 430 km would require nearly 6 m^2 cross-section. A 2 m^2 target could be detected no farther than about 350 km.) Thus there is a question as to whether or not the radar would have detected a jet under these conditions.

One may conclude from this discussion that the high-speed jet explanation is highly unlikely because the radar would not have detected the jet as far away as it did and because jets do not fly at such high speeds over Europe. The fact that the track ended never to be picked up again also argues against a normal aircraft, since there was no place to land in the vicinity other than at Geneva, and, had an aircraft landed there, it would have been tracked as it slowed down and changed its course to head for the airport while flying over the mountains south of Geneva. This track remains unexplained.

New Zealand Sightings, December 31, 1978

Several of the best documented non-military radar and radar-visual sightings ever to occur took place off the east coast of the South Island of New Zealand during the early morning of December 31, 1978. The history of these sightings has been thoroughly documented in several research papers (Maccabee, 1979a,b, 1980, 1987) and books (Fogarty, 1982; Startup & Illingworth, 1980). However, the radar analysis presented here has not been previously published. These sightings are particularly interesting because upper altitude atmospheric data from a balloon ascension were obtained only about an hour and a half before the sightings and because the radar technician responsible for maintaining the radar checked the radar system and also checked for evidence of anomalous propagation (refractive beam bending) during the sightings. Both the upper atmosphere balloon data (temperature, humidity) and the tests carried out by the radar technician show that atmospheric refraction could not account for the interesting radar targets even though skeptics claimed that all the anomalous radar targets were the results of atmospheric effects.

These sightings are probably unique in the history of the UFO subject in that one of the passengers on the plane, a TV news reporter, recorded, during the sightings, his impressions of lights that appeared to be associated with a series of radar detections. There was also a recording made of the pilot's conversations with the air traffic controller at the Wellington Air Traffic Control Center (WATCC). The information to be presented is based on this author's on-site investigation during January and February1979, interviews with all the witnesses, analysis of the original movie film and tape recordings, radar information supplied by the radar technician and air traffic controller, and my subsequent analysis of these events.

These events occurred between about 0010 h (12:10 a.m.) and 0100 h (1:00 a.m.) local (daylight saving) time. During this time the airplane, an Argosy 4 engine freighter, flew southward from Wellington to Christchurch. The flight track of the aircraft is illustrated in Figure 4, along with the times of various events to be described. (There was a second series of events which were visually and photographically more impressive than the ones discussed here as the aircraft flew northward along the same track between about 0200 h (2:00 a.m.) and 0300 h. One of those events has been discussed in depth (see Maccabee, 1987).

The witnesses on board the plane were the captain (pilot) with 23 years of experience and 14,000 h of flying time (Bill Startup), the copilot with 7000 h of flying time (Robert Guard) and a TV news crew consisting of a reporter (Quentin Fogarty), a cameraman (David Crockett), and a sound recordist (Ngaire Crockett, David's wife). This was intended to be a routine newspaper transport flight, from Wellington to Christchurch, carried out by an air crew that was very familiar with night flying off the east coast of the South Island.

The only non-routine aspect of the flight was the presence of a TV crew on board the aircraft. The TV crew was on board because of a series of UFO sightings in the same area ten days earlier. During the night of December 21, there had been a series of radar and visual sightings along the east coast of the South Island. The witnesses to those events were air crews and radar controllers. Those sightings had caught the interest of a TV station in Melbourne, Australia, and the station manager had decided to do a short documentary on them. (Note: The disappearance of young pilot Frederick Valentich over the Bass Strait south of Melbourne, while he was describing an unidentified bright object over his plane (Haines, 1987), had attracted immense worldwide interest in

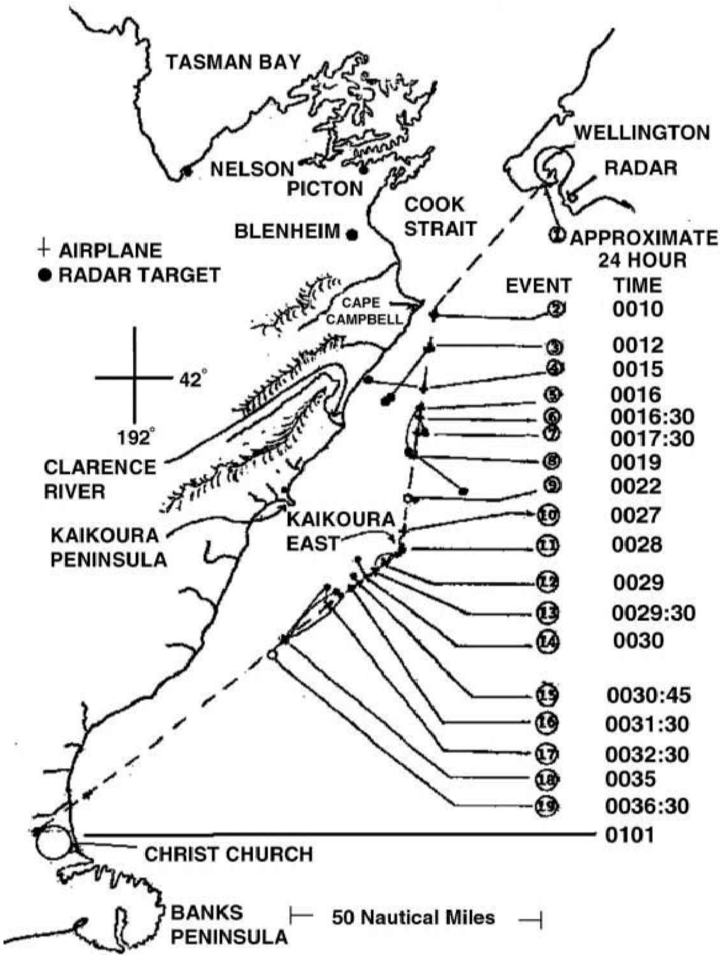

Fig. 4. Track of the aircraft with locations and times of the various sightings.

October 1978. The TV station was trying to capitalize on the residual interest in UFO sightings that had been generated by the Valentich disappearance. The disappearance of Valentich is still a mystery.)

A reporter employed by that TV station, Quentin Fogarty, was on vacation in New Zealand, so the station asked him to prepare a short documentary on the December 21 sightings. Fogarty hired a cameraman and sound recordist and interviewed the radar controllers and a pilot who were witnesses to the previous sightings. He also arranged to fly on one of the nightly newspaper flights to get background footage for his documentary. Naturally, he did not expect to see anything and he was not prepared for what happened. Neither was anyone else!

The witnesses to the targets detected by the WATCC radar were the air traffic controller (Geoffrey Causer) and, for part of the time, the radar maintenance technician (Bryan Chalmers).

It is important to have an understanding of the geographical, atmospheric, and radar context of these sightings in order to properly evaluate the radar data which will be presented. The South Island of New Zealand is quite rugged, with mountain peaks throughout the island with altitudes from 5000 to 12,000 ft (Mt. Cook). (Note: To be consistent with the tape-recorded statements of the air traffic controller to be presented, and with airplane altitudes and speeds, all distances are in feet or nautical miles, nm, unless otherwise noted. 1 nm = 6077 ft = 1.852 km.) The prevailing wind from the west loses its moisture as it passes over these peaks and becomes somewhat turbulent and dry by the time it passes the east coast of the island (the so-called “Kaikoura Coast”) and heads out into the southern Pacific ocean. Under these “Foehn” wind conditions there is moist ocean air below the upper altitude dry air. The radar radiation speed decreases (refractivity increases) with increasing moisture in the air, so the refraction is greater at lower altitudes under these conditions. Hence it is common to have more than normal atmospheric bending under Foehn conditions.

Search radar sets used to monitor air traffic over distances of a hundred miles or more use antennas that create vertical fan beams. The Wellington radar, with a 51 cm wavelength (587 MHz), used an antenna with an aperture 16 m long by 4.3 m high which is shaped as a somewhat distorted parabolic cylinder, with the cylinder axis horizontal. An antenna such as this creates a beam that is broad in the vertical direction and narrow in the horizontal direction. This antenna would have a radiation pattern that is about 2.1° wide in a horizontal plane and the main lobe of the beam would be about 8° high in a vertical plane (Skolnik, 1980). (The vertical radiation pattern is more complicated than this, however, being approximately a cosecant squared shape; see the illustration at the bottom of Figure 5.) The center of the main lobe is tilted upward 4° but there is substantial power radiated at angles below 4°. It is this lower angle radiation that can be bent downward to hit the ground or ocean. Under normal atmospheric conditions the radar can detect land on the northern portion of the east coast of the South Island at distances of about 50 nm. Under the Foehn conditions of anomalous propagation, the radar can detect ground reflections at greater distances as more and more of the portion of the fan beam below 4° elevation is bent downward. Under “really bad” conditions the radar can detect Banks Peninsula about 160 nm from Wellington. Besides detecting the coastline, the radar can also detect ships south of Wellington. The radar does not detect the ocean itself, however, except perhaps at very short distances from the radar installation.

In order to eliminate ground targets not of interest to air traffic controllers, the radar system is generally operated in the “MTI” (moving target indicator) mode in which special electronic circuitry removes from the radar display any

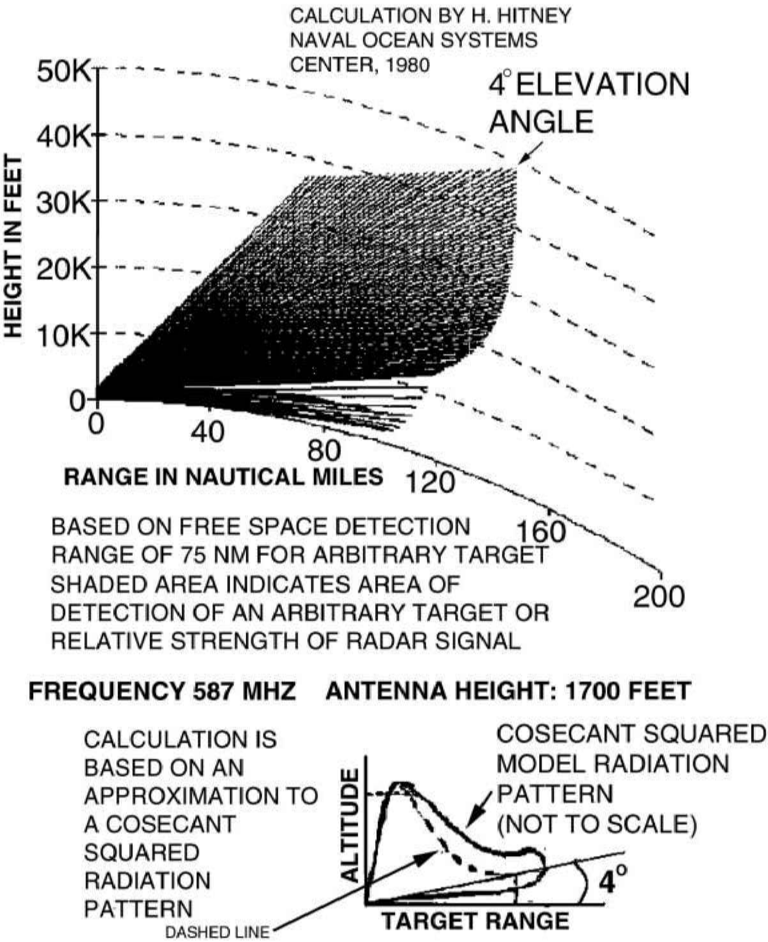

Fig. 5. Calculated radiation pattern for Wellington tower radar based on atmospheric refraction data obtained during a balloon ascension at Christchurch at 2300 h, December 30, 1978.

reflectors which are moving at a speed less than about 15 nm/h. In the MTI mode the radar will display moving but not stationary ships and it will not display most reflections from land. However, the MTI can be "fooled" by reflectors which are able to change the frequency or phase of the radar signal even if they are nominally stationary. This is because MTI operation is based on the Doppler phenomenon mentioned previously: moving objects change the frequency and phase of the reflected radiation. With MTI processing the radar displays, only those reflections for which the echo frequency is different from the transmitted frequency. Frequency changes could be caused by a moving part on a nominally stationary object, the rocking of a boat, *etc*. A reflector which does not move but which changes its reflectivity rapidly, such as a rotating flat plate or some object that shrinks and expands in reflectivity or radar "cross-section," could modulate the reflected radiation and also "escape" the MTI filter electronics. Sometimes even the sweeping of the radar beam across a large target such as the ground can modulate the returned radiation enough to fool the MTI.

History of the Sightings

A history of the various sighting events represented by the numbers in Figure 4 will now be given. At point 1 the aircraft passed over Wellington at about midnight. It reached a non-geographical reporting point just east of Cape Campbell at about 10 min past midnight (point 2 on the event map), where the plane made a left turn to avoid any possible turbulence from wind blowing over the mountains of the South Island. This turbulence had been predicted by the flight weather service, but was not detected at all during the trip. The captain reported that the flying weather was excellent and he was able to use the automatic height lock, which would have automatically disengaged had there been turbulence that would change the altitude of the aircraft. The sky condition was "CAVU" (clear and visibility unlimited), with visibility estimated at over 30 miles. (Note: The definition of visibility is based on contrast reduction between a distant dark object and a light sky. Thus a black object could barely be seen against a bright sky at 30 miles. However, a light could be seen in the night sky for a hundred miles or more, depending upon its intrinsic intensity.) The air crew could see the lights along the coast of the South Island, extending southward to Christchurch about 150 miles away.

At about 0005 h (12:05 a.m.), the captain and copilot first noticed oddly behaving lights ahead of them near the Kaikoura Coast. They had flown this route many times before and were thoroughly familiar with the lights along the coast, so they quickly realized that these were not ordinary coastal lights. These lights would appear, project a beam downward toward the sea, and then disappear, only to reappear at some other location. Sometimes there was only one, sometimes none, and sometimes several. After several minutes of watching and failing to identify the lights the pilot and copilot began to discuss what they were seeing. They were puzzled over their inability to identify these unusual lights and their odd pattern of activity, which made the captain think of a search operation. (Similar activity of unidentified lights nearer to Cape Campbell had been seen by ground witnesses during a series of UFO events that had occurred about ten days earlier. See Startup & Illingworth, 1980).

At about 0012 h, they decided to contact WATCC radar to find out if there were any aircraft near Kaikoura. At this time, point 3 on the map, the plane was traveling at 215 nm/h indicated air speed and had reached its 14,000 ft cruising altitude. There was a light wind from the west. The average ground speed was about 180 nm/h or about 3 nm/min. Since the copilot was in control of the aircraft on this particular journey, the captain did the communicating with WATCC. "Do you have any targets showing on the Kaikoura Peninsula range?" he asked. The controller at WATCC had been busy with another aircraft landing, but had noticed targets appearing and disappearing in that direction for half an hour or more. He knew it was not uncommon to find spurious radar targets near the coast of the South Island. These would be ground clutter effects of mild atmospheric refraction so he had paid little attention to them. About 20 s after the plane called he responded, "There are targets in your one o'clock position at, uh, 13 miles, appearing and disappearing. At the present moment they are not showing but were about 1 min ago." (Note: Directions with respect to the airplane are given as "clock time" with 12:00 — twelve o'clock — being directly ahead of the aircraft, 6:00 being directly behind, 9:00 to the left and 3:00 to the right. The "1:00 position" is 30 ± 7.5° to the right.) The pilot responded, "If you've got a chance would you keep an eye on them?" "Certainly," was the reply. Shortly after that the other aircraft landed and from then on the Argosy was the only airplane in the sky south of Wellington.

At about 0015 h (point 4) WATCC reported a target at the 3:00 position on the coastline. According to captain (7), at about that time the TV crew, which had been below deck in the cargo hold of the aircraft filming a short discussion of the previous sightings, was coming up onto the flight deck. The air crew pointed out to the TV crew the unusual lights and the ordinary lights visible through the windshield. The crew did not see the target at 3:00.

The TV crew had to adapt to the difficult conditions of working on the cramped and very noisy flight deck. The cameraman had to hold his large Bolex 16 mm electric movie camera with its 100 mm zoom lens and large film magazine on his shoulder while he sat in a small chair between the pilot (captain) on his left and copilot on his right. From this position he could easily film ahead of the aircraft but it was difficult for him to film far to the right or left and, of course, he could not film anything behind the aircraft. He was given earphones so he could hear the communications between the air crew and WATCC. Occasionally he would yell over the noise of the airplane to the reporter, who was standing just behind the copilot, to tell the reporter what the air crew was hearing from the WATCC. The sound recordist was crouched behind the cameraman with her tape recorder on the floor and her earphones. She was not able to see anything. She could, of course, hear the reporter as he recorded his impressions of what he saw through the right side window or through the front windows of the flight deck. She heard some things that were more than just a bit frightening.

At approximately 0016 h , the first radar-visual sighting occurred. WATCC reported, "Target briefly appeared 12:00 to you at 10 miles," to which the captain responded, "Thank you." (The previous target at 3:00 had disappeared.) According to the captain (7), he looked ahead of the Argosy and saw a light where there should have been none (they were looking generally toward open ocean and there were no other aircraft in the area). He described it as follows: "It was white and not very brilliant and it did not change color or flicker. To me it looked like the taillight of an aircraft. I'm not sure how long we saw this for.

Probably not very long. I did not get a chance to judge its height relative to the aircraft." This target was not detected during the next sweep of the scope. (Note: Each sweep required 12 s corresponding to five revolutions per minute.)

About 20 s later, at about 0016:30 h , WATCC reported a "...strong target showing at 11:00 at 3 miles." The captain responded "Thank you, no contact yet." Four radar rotations (48 s) later (at point 7) WATCC reported a target "just left of 9:00 at 2 miles." The captain looked out his left window but saw nothing in that direction except stars. Eighty-five seconds later, at about 0019 h, WATCC reported at target at 10:00 at 12 miles. Again there was no visual sighting. The captain has written (7) that he got the impression from this series of targets that some object that was initially ahead of his plane had traveled past the left side. He decided to make an orbit (360° turn) to find out if they could see anything at their left side or behind.

At about 0020:30 h the captain asked for permission to make a left-hand orbit. WATCC responded that it was OK to do that and reported "there is another target that just appeared on your left side about 1 mile... briefly and then disappearing again." Another single sweep target. The captain responded, "We haven't got him in sight as yet, but we do pick up the lights around Kaikoura." In other words, the air crew was still seeing anomalous lights near the coast.

At this time the plane was about 66 miles from the radar station. At this distance the 2.1° horizontal beamwidth (at half intensity points) would have been about 2 miles wide (at the half power points on the radiation pattern). The radar screen displays a short arc when receiving reflected radiation from an object that is much, much smaller than the distance to the object (a "point" target). The length of the arc corresponds roughly to the angular beamwidth. Hence in this case the lengths of the arcs made by the aircraft and the unknown were each equivalent to about 2 miles. If the controller could actually see a 1 mile spacing between the arcs, then the centers of the arcs, representing the positions of the actual targets (plane and unknown) were about 2 + 1 = 3 miles apart.

As the plane turned left to go in a circle, which would take about 2 min to complete (point 9), WATCC reported, "The target I mentioned a moment ago is still just about 5:00 to you, stationary."

During the turn, the air crew and passengers could, of course, see the lights of Wellington and the lights all the way along the coast from the vicinity of Kaikoura to Christhurch, and they could see the anomalous lights near Kaikoura, but they saw nothing that seemed to be associated with the radar targets that were near the aircraft.

During this period of time, the WATCC controller noticed targets continuing to appear, remain for one or two sweeps of the radar, and then disappear close to the Kaikoura Coast. However, he did not report these to the airplane. He reported only the targets which were appearing near the airplane, now about 25 miles off the coast. The TV reporter, who was able to watch the skies continually, has stated (8) that he continually saw anomalous lights "over

Kaikoura," that is, they appeared to be higher than the lights along the coastline at the town of Kaikoura.

By 0027 h (point 10) the plane was headed back southward along its original track. WATCC reported, "Target is at 12:00 at 3 miles." The captain responded immediately, "Thank you. We pick it up. It's got a flashing light." The captain reported seeing "a couple of very bright blue-white lights, flashing regularly at a rapid rate. They looked like the strobe lights of a Boeing 737..." (Startup & Illingworth, 1980).

From the time he got seated on the flight deck, the cameraman was having difficulty filming. The lights of interest were mostly to the right of the aircraft and, because of the size of his camera, he was not able to film them without sticking his camera lens in front of the copilot who was in command of the aircraft. When a light would appear near Kaikoura he would turn the camera toward it and try to see it through his big lens. Generally by the time he had the camera pointed in the correct direction the light would go out. He was also reluctant to film because the lights were all so dim he could hardly see them through the lens and he did not believe that he would get any images. Of course, he was not accustomed to filming under these difficult conditions.

Nevertheless, the cameraman did get some film images. He filmed the takeoff from Wellington, thereby providing reference footage. The next image on the film, taken at an unknown time after the takeoff from Wellington, is the image of a blue-white light against a black background. In order to document the fact that he was seated in the aircraft at the time of this filming he turned the camera quickly to the left and filmed some of the dim red lights of the meters on the instrument panel. Unfortunately, the cameraman did not recall, during the interview many weeks later, exactly when that blue-white light was filmed, nor did he recall exactly where the camera was pointed at the time, although it was clearly somewhat to the right of straight ahead. The initial image of the light is followed by two others but there are no reference points for these lights. They could have been to the right or straight ahead or to the left. The durations of the three appearances of a blue-white light are 5, 1.3 and 1.9 s, which could be interpreted as slow flashing on and off. After this last blue-white image, the film shows about 5 s of very dim images that seem to be distant shoreline of Kaikoura with some brighter lights above the shoreline. Unfortunately, these images are so dim as to make analysis almost impossible.

Although it is impossible to prove, it may be that the cameraman filmed the flashing light at 0027 h . Unfortunately, the camera was not synchronized with either the WATCC tape recorder or the tape recorder on the plane so the times of the film images must be inferred by matching the verbal descriptions with the film images. The cameraman did not get film of the steady light that appeared ahead of the aircraft at 0016 h .

Regardless of whether these blue-white images were made by the flashing light at 0027 h or by some other appearance of a blue-white light, the fact is, considering where the plane was at the time, that this film was "impossible" to obtain from the conventional science point of view because there was nothing near the airplane that could have produced these bright flashes. The only lights on the flight deck at this time were dim red meter lights because the captain had turned off all the lights except those that were absolutely necessary for monitoring the performance of the aircraft. There were no internal blue-white lights to be reflected from the windshield glass, nor were there any blue-white lights on the exterior of the aircraft. The only other possible light sources: stars, planets, and coastal lights, were too dim and too far away to have made images as bright as these three flashes on the film. These images remain unexplained.

There is a similar problem with determining exactly when the reporter's audio tape statements were made since his recorder was not synchronized with the WATCC tape. Therefore the timing of the reporter's statements must be inferred from the sequence of statements on the tape and from the content. Recorded statements to this point mentioned lights seen in the direction of the Kaikoura Coast, as well as, of course, the normal lights along the coast. But then the reporter recorded the following statement: "Now we have a couple right in front of us, very, very bright. That was more of an orange-reddy light. It flashed on and then off again... We have a firm convert here at the moment." Apparently he underwent a "battlefield conversion" from being a UFO skeptic to believer.

The probability is high, although one cannot be absolutely certain that the air crew, the reporter, and cameraman all saw and recorded on tape and film the appearance of the light at 3 miles in front of the aircraft. If true, then this might be the only non-military radar/visual/photographic sighting.

As impressive as this event was, the radar/visual event of most interest here was still to come. At about 0028 h (point 11), the Argosy aircraft made a 30° right turn to head directly into Christchurch. WATCC reported that all the radar targets were now 12–15 miles behind them.

Then, at about 0029 h (point 12 on the map), WATCC reported a target 1 mile behind the plane. About 50 s later (after four sweeps of the radar beam), he reported the target was about 4 miles behind the airplane. Then, that target disappeared, and about 30 s later he reported a target at 3:00 at 4 miles. Two sweeps of the radar beam later he saw something really surprising. He reported, "There's a strong target right in formation with you. Could be right or left. Your target has doubled in size."

The extraordinary condition of a "double sized target" (DST) persisted for at least 36 s. This duration is inferred from the time duration between the controller's statement to the airplane, made only seconds after he first saw the DST, and his statement that the airplane target had reduced to normal size. This time duration was about 51 s (four radar detections over a period 36 s followed by a fifth revolution with no detection plus 3 s), according to the WATCC tape recording of the events. The radar aspects of this DST event will be discussed more fully below.

The pilot, copilot, and the cameraman were able to hear the communications from the WATCC. The reporter and sound recordist could not hear the WATCC communications, but the cameraman would occasionally yell (loudly because of the extreme engine noise) to the reporter what he heard from WATCC. The cameraman told the reporter about the target flying in formation and the reporter started looking through the right side window for the target. The copilot was also looking and after some seconds he spotted a light which he described as follows: "It was like the fixed navigation lights on a small airplane when one passes you at night. It was much smaller than the really big ones we had seen over Kaikoura. At irregular intervals it appeared to flash, but it didn't flash on and off; it brightened or perhaps twinkled around the edges. When it did this I could see color, a slight tinge of green or perhaps red. It's very difficult describing a small light you see at night."

The captain had been looking throughout his field of view directly ahead, to the left, upward, and downward to see if there could be any source of light near the aircraft. He saw nothing except normal coastal lights and, far off on the horizon to the left (east), lights from the Japanese squid fishing fleet which uses extremely bright lights to lure squid to the surface to be netted. Neither the captain nor copilot saw any running lights on ships near them or near the coast of the South Island, which implies that there were no ships on the ocean in their vicinity.

When the copilot reported seeing a light at the right the captain turned off the navigation lights, one of which is a steady green light on the right wing, so that the reporter would not confuse that with any other light. There were lights along the coast but the city lights of Kaikoura were no longer visible, hidden behind mountains that run along the Kaikoura Peninsula. Ireland (1979) suggested that the witnesses saw a beacon at the eastern end of the Kaikoura Peninsula. This beacon is visible to ships at a range of 14 miles from the coast. It flashes white twice every 15 s (on for 2 s, off for 1 s, on for 2 s off for 10 s). The plane was about 20 miles from the beacon and at an elevation angle of about 7°, which placed it above the axis of the main radiation lobe from the beacon.

The combination of the distance and off-axis angle means that it would have been barely visible, if at all. Moreover, the light seen by the copilot and others appeared to be at about "level" with the location of the navigation light at the end of the wing which, in turn, was about level with the cockpit, or perhaps a bit above since the plane was carrying a heavy load. Hence the light was at an elevation comparable to that of the aircraft and certainly above ground level. Many months later, at my request, the air crew attempted to see the Kaikoura beacon while flying along the same standard flight path from Kaikoura East into Christchurch. Knowing where to look for the beacon they stared intently. They reported seeing only a couple of flashes during the several trips they made past the lighthouse. The copilot has stated very explicitly that the unusual light he saw was not the lighthouse.

During this time the reporter also saw the light and recorded his impression: "I'm looking over towards the right of the aircraft and we have an object confirmed by Wellington radar. It's been following us for quite a while. It's about 4 miles away and it looks like a very faint star, but then it emits a bright white and green light." Unfortunately the light was too far to the right for the cameraman to be able to film it (he would have had to sit in the copilot's seat to do that). The captain was able to briefly see this light which the copilot had spotted. This event was a radar-visual sighting with several witnesses to the light.

About 82 s after Wellington reported that the DST had reduced to normal size, when the plane was approximately at point 17, the captain told WATCC, "Got a target at 3:00 just behind us," to which WATCC responded immediately, "Roger, and going around to 4:00 at 4 miles." This would appear to be a radar confirmation of the light that the crew saw at the right side.

Fifty seconds after reporting the target that was "going around to 4:00 at 4 miles," the WATCC operator was in communication with the Christchurch Air Traffic Control Center. He told the air traffic controller that there was a target at 5:00 at about 10 miles. He said that the target was going off and on but "...not moving, not too much speed..." and then seconds later, "It is moving in an easterly direction now." The Christchurch radar did not show a target at that location. This could have been because the Christchurch radar was not as sensitive as the Wellington radar, because the radar cross-section (reflectivity) in the direction of Christchurch was low (cross-section can change radically with orientation of an object) or because the target may have been below the Christchurch radar beam, which has a lower angular elevation limit of 4°.

At about 0035 h, when the plane was about at point 18, WATCC contacted the plane and asked, "The target you mentioned, the last one we mentioned, make it 5:00 at 4 miles previously, did you see anything?" The captain responded, "We saw that one. It came up at 4:00, I think, around 4 miles away, "to which WATCC responded, "Roger, that target is still stationary. It's now 6:00 to you at about 15 miles and it's been joined by two other targets." The reporter heard this information from the cameraman and recorded the following message: "That other target that has been following us has been joined by two other targets so at this stage we have three unidentified flying objects just off our right wing and one of them has been following us now for probably about 10 min." Unfortunately, as already mentioned, the reporter could not hear the communications with WATCC, so he did not always get the correct information. These targets were behind the plane and one of them had been "following" the plane for 7–8 min.

Then, the WATCC reported that the three targets had been replaced by a single target. The captain, wondering about all this activity at his rear, requested a second two minute orbit. This was carried out at about 0036:30 h (point 19). Nothing was seen and the single target disappeared. From then on the plane went straight into Christchurch. The Christchurch controller did report to the aircraft that his radar showed a target over land, west of the aircraft, that seemed to pace the aircraft but turned westward and traveled inland as the aircraft landed. The copilot looked to the right and saw a small light moving rapidly along with the aircraft. However, copilot duties during the landing itself prevented him from watching it continually and he lost sight of it just before the aircraft landed.

Unexplained Radar Targets

It has been necessary to present a history of these events in order to establish the context for the following question: are there logically acceptable explanations in terms of conventional phenomena for the unidentified radar targets and visual sightings? For some, but not all, of the events involving only the radar targets, the answer ranges from perhaps to yes. For the visual events, however, the answer appears to be a firm no. As pointed out above, the film of the three appearances of a blue-white light, regardless of exactly where the plane was when it was filmed, is completely unexplainable because there was just no source for such a light. This is not a question of poor recollection on the part of witnesses or failing to identify coastal lights or other normal lights in the area. Similarly, the visual sightings of lights with beams going downward that appeared and disappeared above Kaikoura (or in the direction toward Kaikoura but closer to the airplane) are unexplained. The sighting of a small light ahead of the aircraft at 0016 h is unexplained because there was simply no light to be seen in that direction. The sighting of a flashing light ahead at 0027 h is likely to have been the light that was filmed) is unexplained, again because there was no light in that direction. And last, but certainly not least, the sighting of a flashing light at the right side for a couple of minutes starting at about 0030:45 h is unexplained because there simply was no light like that to be seen along the distant coastline or in the vicinity of the plane.

But, what about the radar targets that appeared near the plane? Can they be explained in a conventional manner? Following the classic method for explaining UFO sightings (Ireland, 1979; Klass, 1974, 1983; Sheaffer, 1984), one can separate the events and try to explain them individually. In this case that means one analyzes the radar detections apart from any apparently simultaneous visual detections. In approaching this problem one can appeal to the radar/visual “reciprocity relation” first enunciated by Klass (1974): “Whenever a light is sighted in the night skies that is believed to be a UFO and this is reported to a radar operator, who is asked to search his scope for an unknown target, almost invariably an ‘unknown’ target will be found. Conversely, if an unusual target is spotted on a radarscope at night that is suspected of being a UFO, and an observer is dispatched or asked to search for a light in the night sky, almost invariably a visual sighting will be made. In the excitement of the moment it will seem unimportant that the radar target is to the west while the visual target may be east, north or south — the two sightings will seem to confirm one another. Even if the visual sighting is made many minutes or even hours after or before the radar sighting it will be assumed by some that the presence of the UFO has been positively confirmed by what is usually called 'two independent sensors.'"

Klass has trivialized the situation by suggesting that a radar target will be associated with a visual sighting even though they are in different directions or widely separated in time. This might happen "in the heat of the moment" during a sighting, but an investigation and analysis would rule out any case where there was an obvious difference in time, direction or distance between a radar target and the visually sighted light or object. In two instances described above, at 0016 h and 0027 h, a light was observed in the direction of a radar target as soon as the witnesses were alerted to look in that direction (ahead of the plane). These would seem to be a "solid" radar/visual sightings because the times and directions matched. Although the timing was not as exact during the DST event at about 0031 h, the witnesses did see an unexplained light in that time frame and then the radar seemed to confirm a light at "at 3:00 behind us" as reported about 82 s after the end of the DST event. Of course, the witnesses could not determine how far away any of the lights were so there was no chance of a match in distance.

The only marginally acceptable argument for these radar/visual events is essentially "statistical": there were so many unidentified radar targets caused by atmospheric effects appearing and disappearing along the coast that the chance of such a radar target appearing at the same time and in the same direction as a light ahead of the plane would be quite good. The problem with this argument is that the "normally anomalous" radar targets, presumably the normal ground clutter resulting from normal atmospheric refraction, were appearing and disappearing close to the coast, whereas the targets reported near the airplane were more than 20 miles from the coast where there was no ground clutter.

The application of Klass' reciprocity principle to these sightings is quite straightforward. The radar operator said he had noticed unidentified targets appearing and disappearing along the coast in a manner typical of the area for some time before the Argosy air crew asked him if there were targets near the Kaikoura Coast. He paid no attention to them until the air crew called him. The air crew called WATCC because they had spotted lights appearing and disappearing, lights which appeared to them to be just off the coast or above the city lights of Kaikoura. Consistent with Klass' principle, the radar controller reported to the crew that he did have targets, although they were closer to the plane than the distance estimated by the crew to the lights. Of course, it is virtually impossible to estimate distances to lights at night (unless you know something about them), so the distance discrepancy is not of great importance. During the following 25 min or so the radar operator reported many radar targets. Most of the time the radar target reports did not lead to visual sightings, so the principle was violated more times than it was obeyed. All this means is that the witnesses were more discriminating than the principle would imply (less discriminating witnesses might have reported seeing lights which turned out to be stars and planets that might have been in the directions of the radar targets).

Klass (1983), in a chapter on these sightings, discussed some of the radar and visual events described here but he did not mention the radar/visual at 0027 h, nor did he mention any of the film images. Sheaffer (1984) wrote of the 0027 h event, "This is the first apparently consistent radar/visual incident of the flight." He did not propose an explanation for it. (He did not mention the 0016 h event.) Ireland (1979) did not discuss specifically the radar detections near the airplane but rather implied that they were only some of the many "normal" unidentified radar targets that are always detected off the coast of the South Island. He did mention the visual sightings at 0016 and 0027 h and suggested that the witnesses misidentified the lights of Christchurch. This suggestion makes no sense, however, because the unidentified lights were not in the direction of Christchurch and because they had been able to see the Chistchurch lights (or a glow in the sky above the city lights) continually during the trip. His explanation for the light at the right side at 0031 h, the lighthouse on the Kaikoura Peninsula, has already been discussed.

All of the discussion about radar targets to this point has not tackled a fundamental question which is, what is the significance of transient targets that appeared near the aircraft? A related question is, what was reflecting the radiation, since the presence of any target return on the radar screen means that something has reflected the radiation? The trivial answer that some unknown airplane was being detected, is not relevant here. During these sightings there was only one known aircraft in the sky.

Radar Angels

The subject of unidentified targets and radar "angels" has a history that starts during WWII. Radar sets designed to detect enemy and friendly aircraft at long ranges were observed to pick up occasional targets not related to aircraft. Sometimes these targets could be associated with known reflectors, such as when, for example, a slowly moving target was identified with a ship traveling at sea or a vehicle moving over the land. At other times the land or ocean was detected, but in these cases the returns generally covered small areas of the radar scope rather than appearing as isolated point targets. But often there was no obvious cause for a target. The targets for which there was no obvious cause were labeled "angels."

After WWII radar scientists began to study the angel phenomenon. They determined that radar could detect flocks of birds or single birds, weather phenomena such as precipitation (rain, snow) and lightning, meteor ionization trails and even insects under the proper conditions of high sensitivity. The most sensitive radar set could also detect turbulent areas in the atmosphere where there was nothing visible, areas of clear air turbulence or "CAT" as mentioned previously. Things as small as individual birds and insects and as ephemeral as CAT would make small, weak targets on a radar scope. Such targets might appear on one rotation and not on the next, whereas identifiable targets such as airplanes or surface vehicles would appear on consecutive rotations. A normal moving object would make a trail of arc returns. The trail of arcs would exist because of the persistence of glow of the radar screen. Each arc would be visible, though gradually fading, for several sweeps of the radar so that the operator could determine the speed and direction of travel from the line made by the successive arcs.

The radar scientists also determined that atmospheric refraction could bend beams downward so that objects at lower altitudes or on the ground, objects which would not ordinarily be detected because they were below the beam, could be detected. Radar antennas generally radiate some power down toward the ground (the bottom of the main lobe of the radiation pattern) and the atmosphere always bends the radiation downward by some amount. Therefore each search radar set detects some "ground clutter" close to the radar set. How far away from the radar set this ground clutter extends depends upon refraction in the atmosphere which bends the main radiation lobe downward. During conditions of large refraction the ground clutter reflection could extend a great distance and the radar could detect targets on the ground that would ordinarily be too far away to detect. For example, a building at a distance of some miles from a radar set that would ordinarily be below the "radar horizon," under conditions of strong refraction could appear as a point target within the ground clutter. (Condon & Gillmor, 1969, and Skolnik, 1980, provide good reviews of the research on clutter and angels.) The use of MTI, as described previously, would reduce the amount of ground clutter. However, MTI filters are not perfect. For various technical reasons related to oscillator stability, atmospheric scintillation, beam rotation, *etc.*, returns from stationary or very slowly moving targets can get "through" the MTI filter.

Thus experiments showed that the clear atmosphere could cause radar targets to appear at unexpected locations in two ways: (a) bend the radar beam downward so that it detected something normally below the beam and (b) act as a reflector itself at locations of considerable turbulence or where there were sizeable gradients in refractivity.

The next question is, could any of these potential radar reflectors, birds, insects, or CAT or targets below the radar horizon explain the unidentified Wellington radar detections? If one considers only the targets near the coast the answer is yes. At the coastline there was some turbulence and there was varying atmospheric refraction. The refraction is a time-dependent effect that can cause the radar illumination of ground reflectors to change such that certain weak reflectors might appear one moment and disappear the next. This is like normal optical scintillation of the atmosphere (*e.g.*, the rather large fluctuations in brightness and the very small fluctuations in direction of a star or distant light on the horizon).

If, for example, a particularly strong reflector on the ground, like a metallic building roof, were illuminated strongly during the first sweep of the radar beam and not during the second it would appear as a point target that "disappeared." (This point target might be embedded within a larger "area target" created by the ground reflectors around it.) If another strong reflector not far away happened to be picked up on the second sweep the radar operator might interpret the disappearance in one location and the appearance in another location as resulting from the motion of a single reflector during the sweep cycle time. Under conditions of strong, turbulent refraction there might be numerous small (point) reflectors being illuminated by varying amounts and creating numerous point targets that would appear and disappear on the radar scope thereby giving the impression of motion of some object or objects.

Although the ocean is not as strong a reflector as the ground, it is also possible to pick up reflections from waves and, of course, ships. Hence strong refractive conditions could, in principle, cause the radar to detect anomalous targets on the ocean surface which, because of the time dependence of the refraction, might appear to move around. Herein lies the core of the idea suggested by Klass and Ireland to explain the targets detected near the aircraft. One problem with applying this sort of explanation to the targets near the airplane is that the airplane traveled over quite a distance and so the area in which there were potential surface radar targets must have been at least that long and at least several miles wide. That means there would have been numerous ships or large metal buoys on the surface to reflect the radiation since the ocean itself was not a sufficiently strong reflector of grazing radiation to create targets at distances of 50 miles or more from the Wellington radar.

Furthermore, since the radar horizon was 47 miles very little radiation was available to detect surface objects that were beyond 50 miles (only the small amount of radiation that was bent over the horizon). To accept this explanation one would also have to assume that variations in the orientation of an object or variations in the radar beam illumination of a particular object would make it appear for only one sweep or for several sweeps of the radar screen at the time that the object and the airplane were the same distance from the radar and not appear again until the airplane was so far from it that it was no longer of interest to the radar controller, so he didn't report it.

Another problem with assuming that the transient targets were occasional reflections from buoys or stationary boats on the ocean surface is that targets such as these should not have shown up anyway since the viewing scope was operated in the MTI mode using an electronic filter that rejects slowly moving and stationary targets. In other words, there must have been something about these targets that changed the frequency and phase of the radiation as they reflected it even if they weren't moving.

There is yet another possibility for random target detections, namely, one of the known types of radar "angels:" birds, insects and CAT. However, the sensitivity level of the Wellington radar and the MTI processing makes it highly unlikely that any of these could be detected at ranges of 50–100 nm from the radar (see Appendix).

One may conclude from the discussion thus far that the radar targets detected near the coast could be explained as the effects of normal atmospheric refraction causing the radar to illuminate ground targets in a random manner. However, this is not a convincing explanation for all the targets that were observed near the airplane. And none of these is a satisfactory explanation for the Double Sized Target.

Double-Sized Target

Klass (1983) says of the DST incident, "This indicated that either anomalous propagation conditions existed or that, if there was a UFO in the area, it was now flying so close to the aircraft that the two appeared to be one to the Wellington radar." Ireland (1979) did not comment about this or any of the specific radar detections but instead made the following general comment after discussing the occurrence of radar anomalies (ground clutter, ordinary "radar angels") that often occur along the Kaikoura Coast: "If we accept the hypothesis that the weird echoes seen on the Wellington radar were related to the atmospheric conditions prevailing, then we have reasonable grounds to expect that the apparent coincidences of the ground radar echoes and nocturnal lights seen form aircraft were largely unrelated." In other words, if we assume that there are lots of normal "radar angels" and unidentified targets, such as discussed in the previous paragraphs, then the seeming correlations between radar targets and lights could be just accidental, in which case we could treat the lights separately from the radar targets. Ireland's reasoning implies that there were no true radar-visual sightings.

The explanations proposed by Ireland and Klass are consistent with the general suggestion by Von Eshleman that anomalous propagation can explain radar UFOs, and he, too, would probably propose that the DST was caused by anomalous propagation. However, it is not sufficient to merely propose a potential solution and then walk away from the problem. The scientific approach is to propose an explanation, to set up a realistic scenario based on the proposed explanation, and then to try to prove or disprove it. This process requires the analyst to be more specific than simply saying, as did Klass, that the DST was a result of either a UFO or anomalous propagation, with implication that the obvious scientific choice is anomalous propagation. The analyst must take the time necessary to fully understand the implications of the available sighting data and to make the comparison with the proposed explanation.

Any proposed explanation based on atmospheric effects must answer the following questions: (a) from the point of view of the radar receiver, what would the atmosphere have to do to the airplane radar echo to make the electronic system generate and display an arc twice the normal length, (b) could the atmosphere do this, in principle, (c) what would be the quantitative requirements on the atmosphere for this to occur, and (d) were the atmospheric conditions compatible with these requirements? In other words, were the propagation conditions sufficiently "bad" that the radar return from the Argosy aircraft could actually double in size? Finally, if there is no reasonable way in which the atmosphere alone could have created the DST, is there any way in which the atmosphere could have "participated" along with some other phenomenon in the creation of the DST?

During the DST event, the arc representing the aircraft return approximately doubled in length after a target had been at 3:00 at four miles and, according to the controller and the technician, this expanded arc moved, without distortion, along the screen. It was seen on four rotations which means it moved like this for at least 36 s. During this time the plane moved about 1.8 miles. Then on the next rotation the airplane target was back to its normal size. Thus we have essentially four "samples" of an abnormal situation, each sample being roughly 0.067 s long (the fraction of time the rotating beam 2° wide illuminates a target), with the samples separated by 12 s. What this means in detail will now be described.

The controller said that the other target flying with the plane could be left or right, which means that the growth in target size was symmetric, *i.e.*, the centers of these expanded arcs aligned (in a radial direction away from the center of the radar display) with the centers of the preceding arcs on the radar display. To understand this situation, imagine looking down from high in the sky above the Wellington radar center and seeing the radar beam rotating around in a clockwise direction. Under normal conditions (before and after the DST), because of the 2° width of the beam, it would "contact" the plane when the center of the beam was about 1° to the left of the direction to the plane. At this point in the beam rotation, as portrayed on the radar scope, the echo strength from the aircraft would suddenly become strong enough for the display to create a bright target. This would be the left end of the bright arc representing the airplane. The beam would then rotate past the plane, thereby creating an arc about 2° wide on the display. The bright arc would end when the center of the beam was about 1° to the right of the direction to the plane. During each rotation before the DST the radar electronics created a 2° arc and, because of the persistence of the glow on the screen, at any time there was a trail of arcs making a straight line (the track of the airplane) along the scope. The actual position of the airplane was at the center of each arc.

In order to gain a concept of what happened during the DST condition, one might imagine that the beam first contacted the plane when the beam centerline was 1.5°–2° to the left of the direction to the plane. The beam then rotated past, creating an bright arc 3°–4° long (or approximately double the normal length) on the scope, with final detection when the center of the beam was 1.5°–2° to the right of the of the direction to the plane. In other words, it was as if the beam detected the plane about 1° "too early" in the rotation and broke contact with the plane about 1° "too late" in the rotation. However, a careful analysis of the manner in which radar detects and displays echo information indicates that the actual situation was not this simple. To fully understand what the DST condition signified one would need to be able to accurately characterize system "non-linearities" including (1) the exact radiation pattern of the antenna (this can be approximated, but it is not accurately known), (2) the nature of the electronic processing system (non-linear because of limiting or automatic gain control) and (3) the gain (amplification) settings and non-linear response of the radar display (a cathode ray oscilloscope for which the spot size and brightness is a function of the signal amplitude that reaches the display).

In principle, the extra arc length could have occurred if the radar beamwidth suddenly doubled from 2° to 4°. However, this could happen only if either the antenna split in half or the radar frequency suddenly decreased to half of its normal value, either of which would double the diffraction angle (which determines the width of the radiation pattern). Only a catastrophic mechanical or electrical failure of the radar system could cause one of these situations to occur and it would not "self-repair" after 36 s. Hence the temporary doubling of the beam width is not an acceptable explanation.

There are two other possibilities: (1) two equally reflective objects suddenly began to travel with the airplane, one at the left and the other at the right, and they were within a mile or so of the airplane, *i.e.*, they were so close that the radar arcs of these objects merged with the arc of the airplane (thereby making an arc about 4° long) or (2) the amplitude of the echo from the direction (and distance) of the plane increased by some factor that would double the arc length (the echo amplitude probably would have more than doubled because of system non-linearity). The first possibility is easy to understand, but it requires the existence of two unidentified objects flying with the plane. The second is not so easy to understand because of the system non-linearities mentioned at the end of a preceding paragraph, but it does allow for the possibility of a non-UFO explanation. The second possibility can be investigated by replacing the non-linearity of the system with a simple proportionality which would likely underestimate the required change in echo strength. (The arc length would probably be proportional to the echo strength raised to a fractional power rather than to the echo strength raised to the first power.) That is, one may simply assume that the arc length of a target on the radar display would increase in proportion to echo amplitude. With this assumption of simple proportionality the question becomes, what would have to happen to (at least) double the echo strength?

The echo could increase in strength for either one, or a combination of, these reasons: (1) the reflection strength or radar cross-section of the airplane increased, (2) the atmosphere temporarily focused radiation, and (3) another radar reflective object with a cross-section equal to (or more likely, greater than) that of the airplane appeared close to the plane in range and azimuth (but could be considerably above or below, because of the fan-shaped beam) and traveled at the same speed. Regarding (a), the cross-section of an airplane is a function of the viewing aspect, the most noticeable variation being that the "side view" can have a cross-section many times larger than the end view.

However, in this case the Argosy aircraft was flying in a straight line nearly away from the radar and therefore it maintained a constant orientation and a constant cross-section, so (a) is rejected. Suggestion (c) is, of course, the explanation offered immediately by the air traffic controller when he said a target was traveling with the airplane. The implication is that, at least during the DST event, the cross-section of the unidentified target was approximately equal to that of the airplane so that the radar echo was about twice as strong as from the airplane alone. Why the cross-section of the unknown object would suddenly increase as if this object just appeared out of nowhere and then decrease to zero as the airplane target "reduced to normal size" is not known but, of course, could be evidence of a reorientation of the object or it could be evidence that the object moved a several miles (at least) between radar beam rotations. All we really know about this hypothetical object is that for 0.13 s during each beam rotation (the time it took for the beam to sweep across the target, $(4^{\circ}/360^{\circ}) \times 12$ s = 0.133 s) it was at the same azimuth as the airplane and at the same distance (to within ± 1/2 mile), although it could have been above or below by thousands of feet because of the vertical fan shape of the radar beam.

Suggestion (2) is one type of explanation based on atmospheric effects. This explanation requires that the atmosphere act like a lens and focus radiation. It would focus the transmitted pulse from the antenna onto the airplane and would focus the airplane echo back onto the antenna. This would essentially be a "magnifying mirage" effect which would make the airplane have twice its usual cross-section. For this to happen the atmosphere would have to form a strange sort of cylindrical lens with a horizontal axis and refraction distributed throughout the atmosphere between the plane and the radar antenna. All rays are bent some amount by the atmosphere so the normal ray path between the antenna and the airplane would have some convex-upward curvature (*i.e.*, it would travel upward to a maximum height and then downward as it moves along a horizontal distance). To get a concentration of rays the refraction below the altitude of the plane would have to diminish somewhat so that rays of echo radiation that would ordinarily pass below the radar antenna would be "bent upward" to reach the antenna.

Simultaneously, the refraction above the airplane would have to increase slightly so that rays of echo radiation that would ordinarily pass above the antenna would be "bent downward" and reach the antenna. The effect of this sort of bending would be to concentrate more transmitted radiation power on the airplane and to concentrate more reflected power on the antenna than it would ordinarily receive, thereby creating a larger arc on the radar screen. Could this happen? Yes, under some atmospheric conditions for targets at low altitude where there is substantial moisture and temperature inversion and so the refractivity can change considerably with height. However, the calculated radiation pattern in Figure 5 (top), which is based on the refractivity *vs.* height, Figure 6, shows no such concentration of rays, although it does show some

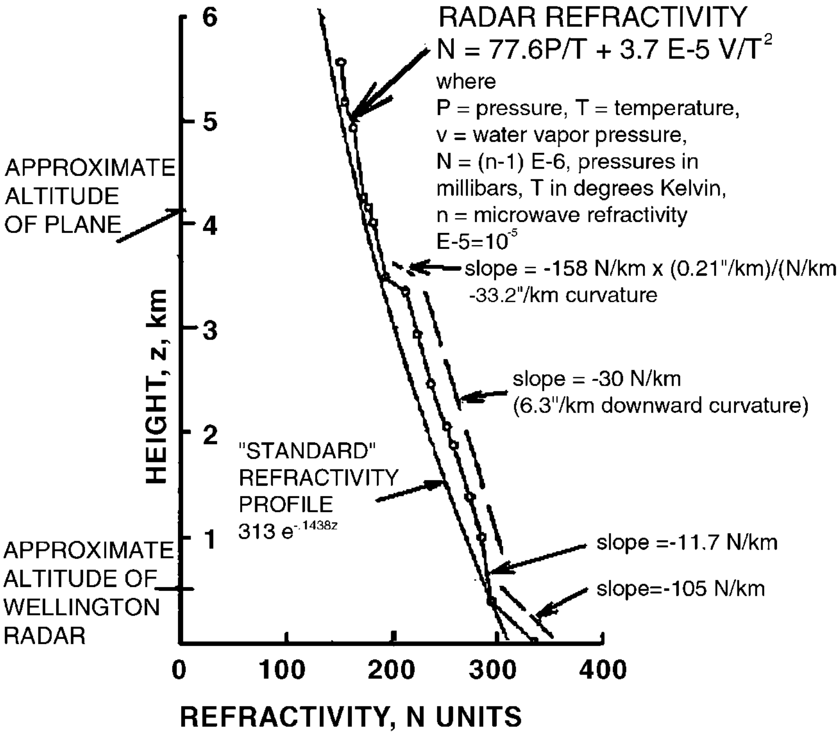

Fig. 6. Refractivity profile at Chistchurch, NZ. Calculated from the balloon launch data of 2300 h, December 31, 1978. Multiply N values by $0.21''/N$ to get curvature in seconds of arc per horizontal kilometer traveled. Negative signs mean curvature is downward. Only at 3.4 km altitude was the refractivity sufficient to cause bending that exceeds the curvature of the earth (*i.e.*, trapping) which is 33″/km.

effects of downward bending of radiation at altitudes below the airplane (Davis & Hitney, 1980).

Generally the refraction diminishes with increasing altitude because the air density and moisture decrease. Since ray bending is essentially proportional to the change in refractivity with height, *i.e.*, to the inverse of the slope of the refractivity as shown in the graph in Figure 6, the bending also generally decreases with height. (Note: Figure 6 shows that there was a small height region (3–3.5 km) over which the refractivity decreased fast enough to trap any rays that might be emitted horizontally by an antenna at that height, *i.e.*, a weak radar duct. Trapped rays would travel at the altitude of the duct. Any rays not emitted exactly horizontally at the altitude of the duct would quickly leave the duct.) A condition in which the refraction increased with altitude is a condition that is opposite to what would be expected under the Foehn wind conditions of dry air at high altitude above moist air near the ocean (because refractivity increases with moisture content of the air). The known weather conditions were not compatible with the refractivity conditions required for an "atmospheric lens" starting at the radar antenna and reaching up to the airplane, so atmospheric "magnification" over a period of 36 s cannot be the explanation.

Since atmospheric refraction acting directly on the reflection from airplane cannot explain the DST, one must investigate other possibilities. One possibility is based on the bending of radiation down to some reflector, *i.e.*, a ship, on the ocean surface. Assume there was a ship directly under the airplane and that the radar suddenly picked up this ship for 36 s. The combined radar cross-section of the ship and airplane might double the echo strength and this could double the arc length on the scope. However, there are two reasons why this explanation is not satisfactory. One is that the aircraft was about 84 nm from the radar antenna and therefore over the radar horizon (47 nm for the radar antenna at 1700 ft altitude). Refraction was not great enough that night to cause radiation to hit the ocean surface that far away (see Figure 5). The second problem is that the airplane traveled about 2 nm during the DST condition but the front to back thickness of the arc, which corresponds to about a 1 mile range resolution, did not change, according to the witnesses. If the radar picked up a ship on the surface that was exactly at the same distance as the plane when the DST began, by 36 s it would become apparent to the radar operator that the plane was moving past a stationary object. Since, according to the controller, the arc moved along the screen without distortion this cannot be the explanation.

One might try to correct this explanation by assuming that the magnitude of atmospheric refraction (that caused the hypothetical ship to be detected at 82 nm by a "bent" radar beam) immediately started to increase thereby increasing the magnitude of bending of the beam and also the overall length of the beam path to the ship. Because the ray paths from the vertical fan radar beam are convex upward, the increase in refraction with increasing altitude would cause the beam path to rise higher and higher into the atmosphere as time goes on. However, the curvature change could not accommodate an increase in ray path length at a rate of 3 nm/min for 36 s. This would require the top of the curved ray to move upwards into the thinner atmosphere where the refractive bending is less at exactly the time when increased bending would be required, under this hypothesis. Hence, there is no way that the radar return from a stationary or slowly moving target on the ocean surface could explain the DST even if excessive atmospheric refraction were occurring.

There is a way that a stationary object on the ocean surface could facilitate an anomalous detection of the aircraft itself. Specifically, one might imagine a highly unusual situation in which there was a large ship exactly in the same direction as the airplane but only about half as far away (30–40 nm) and therefore not over the radar horizon. Some of the radiation bent downward by refraction could be reflected from this ship toward the airplane. In this case the aircraft would be illuminated by the sum of direct plus reflected radiation, a larger amount of radiation than ordinary. (The radiation reflected from the hypothetical ship would not be in phase with that which traveled directly from the antenna to the airplane, but that probably would not matter.)

The echo received by the antenna would be due to the sum of the direct and reflected radiation. There are also other ray paths that would increase the echo strength, such as direct to the airplane, then reflected off the ship and back to the antenna and "higher order" reflections of much lower amplitude (antenna to ship to plane to ship to antenna, *etc.*) This hypothesis satisfies the requirement that the enlarged radar target travel at the same speed as the airplane because both the direct and reflected radar paths would increase at the same rate. However, unless the ship were a large, properly oriented flat plate (aircraft carrier), the radiation hitting the ship would be scattered in many directions and so "ship-reflected" radiation that reached the airplane would be much weaker than the direct illumination. It might be intense enough to increase the arc length a small amount but it certainly would not be strong enough to make the arc length twice the size of the airplane alone. Therefore it is unlikely that a proper alignment of surfaces on a ship, needed in order to cause a reflection such as proposed here, could actually occur.

Furthermore, ships tend to roll about in the ocean, so even if there were at some instant a proper alignment, the probability is low that the same optimum alignment would occur four times at 12 s intervals and never again. Thus it appears that an intermediary reflection from a ship could not explain the DST. The fact that the crew saw no ship running lights on the ocean surface must also be considered, since most vessels leave lights on at night to prevent collisions. (Note: The possibility that a strong gradient in refraction at the boundary between two dissimilar atmospheric layers either above or below the aircraft could act as a mirror was investigated. The conclusion, based on theoretical concepts described by Condon and Gillmor, is that any such reflection would be far to weak to be detected.)

In order to investigate the possibility that atmospheric anomalies could explain the DST, I contacted Atlas (1980), an expert in atmospheric effects on radar. He pointed out that typical "dot angels", *i.e.*, echoes from birds, insects and CAT, probably could be detected by the Wellington radar, but he doubted that these could be detected at a distance as great as 80 nm. When told of the DST his immediate response was, "UFO." Then he suggested a closer look at the capabilities for detecting birds or flocks of birds at long distance, although the evidence that the DST persisted for at 4 radar rotations did bother him because that would seem to imply birds could fly as fast as the aircraft, an obvious impossibility. As a result of Atlas' comments, I made an estimate of the minimum radar cross-section for detection by the Wellington radar (see Appendix). I also consulted with Lothar Rhunke, Dennis Trizna, and Donald Hemenway, radar and atmospheric scientists at the Naval Research Laboratory.

As part of this investigation I compared the Wellington radar with research radar results obtained by Atlas, Rhunke, and Trizna. The result of this investigation was that the radar might have been able to detect a flock of birds at 82 nm but not insects or clear air turbulence. (Note: Because of the vertical fan shape of the beam the birds could have been at the range and azimuth of the plane and at any altitude above about 3000 ft. In order to accept the bird explanation one has to assume that the MTI did not reject the birds for some reason.) A single flock of birds might have the effect of increasing the airplane radar target for one and perhaps two rotations of the radar if the flock happened to be 82–83 nm from the radar. However, it could not increase the size of the target for three or more rotations without it becoming apparent to the operators that the plane was traveling past something essentially stationary. One might try to imagine a bizarre "arrangement" of four flocks separated by 0.6 nm (the distance the plane traveled during one beam rotation) and lined up in the direction of the plane, but this still requires an explanation as to why all four hypothetical flocks were not detected on each rotation, as well as before and after the DST event.

The possibility that some very unusual sidelobe effect caused by power not radiated into the main radar beam could have created the DST, has been considered and rejected because of the relative weakness of the sidelobes. Hence, it appears from the above discussion that no satisfactory explanation based on conventional understanding of the radar and atmosphere has yet been proposed for the DST. It must remain an unexplained radar anomaly. Of course, the close temporal and spatial association between the DST and the preceding nearby target and between the DST and the subsequent light at the right side (with a subsequent radar detection at the right) suggests that there was one (or more) real, *i.e.*, radar reflective, object (or objects) capable of high-speed travel that was moving along with the airplane, perhaps above, below or behind (or, if two objects, at the left and right) during the DST event. What could be the cause for such an object(s)? Any specific suggestion would be pure speculation. However, this case analysis shows that speculation is justified because "UFOs are real."

Conclusion

Contrary to the opinion presented by the SSE Review Panel "old cases" do contain valuable information. Moreover, some radar and radar-visual sightings cannot be explained merely by a general appeal to vagaries of the atmosphere and radar systems. In some cases one can conclude that the atmosphere and atmosphere-associated phenomena (birds, CAT, *etc.*) were not the cause of the anomalous detections. These cases should be recognized for what they are, detections of anomalous objects, some of which appear to be under intelligent control, but which are not artifacts of human technology or known natural processes.

Appendix

The sensitivity of any radar system is based on the power transmitted, the antenna size and shape (which determine the beam width), and the electronic processing system. The latter determines the noise level below which an echo cannot be detected. The calculation here is for single echo detection with no special processing. The intent of this calculation is to provide an approximate sensitivity of the Wellington radar system. An exact value cannot be determined since there are several unknowns such as the exact noise figure and the exact electronic gain factors built into the signal processing.

The simple radar equation (Skolnik, 1980) is based on the idea that a certain amount of power, P_t, in a radar pulse is concentrated into a beam of some angular size and projected outward by an antenna. At the range R the beam covers an area given approximately by $[(\lambda^2/kLw)R^2]$, where L is the length and w is the width of the antenna, λ is the wavelength of the radiation, and k is a factor less than unity that accounts for the fact that the solid angle of diffraction is not simply equal to the geometric ratio, λ^2/Lw. The product $kLw = A$ is an effective area of the antenna, which is smaller than the geometric area. An object, the radar target, has an effective area, C, called the "radar cross-section." The target intercepts a fraction of the beam power that is proportional to the area ratio, $C/[(\lambda^2R^2)/(kLw)] = (CA)/(\lambda^2R^2)$. The target scatters this radiation into all directions (4π steradians). At the distance of the antenna this radiation covers an area $4\pi R^2$. The antenna captures $A/(4\pi R^2)$ of the reflected power. Hence the received power is given approximately by:

$$P_r = \frac{A^2C}{4\pi\lambda^2R^4}P_t = \frac{G^2\lambda^2C}{(4\pi)^3R^4}P_t \tag{1}$$

where the antenna gain is $G = (4\pi A)/\lambda^2$ (see, *e.g.*, Condon & Gillmor, 1969, p. 660). The atmosphere does not enter into this equation because absorption and scattering are negligible in the clear atmosphere at the wavelengths of interest here.

This received power must be greater than the basic electronic noise of the radar system in order for single pulse detection to occur. The noise level is given by a product of the electronic (thermal or Johnson) noise within the bandwidth, B, of the receiver system and an antenna noise figure, N_f:

$$N = kTBN_f \tag{2}$$

where k is Boltzmann's constant, T is the temperature, and kT is the thermal noise power per hertz (white noise, uniformly distributed throughout the bandwidth of interest) which is about 4×10^{-21} W/Hz at room temperature. The bandwidth is at least as large as (and probably larger than) the inverse of the pulse duration, T_p. For single pulse detection I have assumed $P_r = 2N$. With this information the second form of Equation (1) can be used to find the minimum detectable cross-section, C_{min}:

$$C_{min} = \frac{2(4\pi)^3 R^4 (kTBN_f)}{\lambda^2 G^2 P_t} \tag{3}$$

According to the radar technician the Wellington radar has (had, *circa* 1978) the characteristics outlined in Table 1.

According to these specifications the bandwidth would be about 4×10^5 Hz and $N_f = 10^{0.4} = 2.5$ so $N = kTBN_f = 4 \times 10^{-15}$ W. Therefore the minimum echo

TABLE 1
Characteristics of Wellington Radar, *circa* 1978

Type:	Marconi 264 (similar to S650H with S1055 antenna). The radar system had undergone extensive modernizing in the late 1970s. This modernizing had the effect of making the MTI display more sensitive than the raw radar display. (Note: The insertion of MTI filters actually reduces the fundamental sensitivity of the radar, so in the Wellington radar system the raw radar display was not operated at its theoretical maximum capability.)
Power:	500 kW
Frequency:	587 MHz ($\lambda = 0.51$ m, UHF radar)
Pulse Duration:	2.7 μs (2.7×10^{-6} s)
Pulse Repetition Rate:	Variable, averaging 500/s
Antenna Dimensions:	4.3 m high by 16 m long, parabolic; 69 m^2 area
Antenna Gain:	30 db over a dipole
Beamwidth	$2.1 \pm 1°$ horizontal; cosecant squared radiation pattern; the lower lobe of the radiation pattern is about 7° wide vertically
Antenna Tilt:	The lower lobe of the radiation pattern tilted 4° upward
Antenna Height:	1700 ft above sea level
Polarization:	Horizontal
Revolution time:	12 s
Noise Figure:	Estimated at 4 db
MTI:	Used phase shift and digital scanning electronics; set to exclude normal targets at radial velocities under 15 nm/h; observations of known targets with MTI on and off indicated that the MTI processing made the targets more visible on the display; apparently strong targets on the MTI display could be weak or non-existent on the display when the MTI was switched off
Absolute Distance Accuracy:	1% of full scale
Relative Distance Accuracy:	About 1 mile on maximum range scale
Maximum Range:	150 nm
Display:	Plan Position Indicator (PPI), operated on the maximum range scale during these sightings; 10 nm range rings indicated on the display

strength for detection would be about 8×10^{-15} W. The antenna gain of a dipole is 2 db (over the gain of a spherical radiator) so the total gain of the antenna is rated at 32 db = $10^{3.2}$ = 1585. (Note that the actual area of the antenna is about 69 m^2 so the gain "ought" to be $[(4\pi \times 69)/(0.5)^2 = 3468$. Hence the factor k, defined above, is 1585/3468 = 0.45. In other words the effective area is about half the actual area.) This means that in a direction along the axis of the radar beam there is 1585 times more power per unit area than there would be if the antenna radiated uniformly at all angles, *i.e.*, as a spherical radiator. Since the antenna main lobe was tilted upward by about 4° and since the aircraft was at an angular elevation of about 1.4°, it and presumably any other potential "UFO" targets such as birds were below the axis of the beam.

This means that the actual power radiated in the direction toward these targets was lower than that radiated along the axis of the main lobe by an unknown factor (unknown because the exact shape of the radar beam, as affected by the atmosphere at that particular time, is unknown). The best approximation to the actual gain factor in the direction of the airplane is provided by the radiation pattern in Figure 5. The outer boundary of the pattern indicates that an object that can be detected at some distance when on the main axis of the beam at 50,000 ft, can be detected at 70% of that distance if it were at 14,000 ft. Since the detection range is proportional to the square of the gain and varies inversely as the fourth power of the range, it must be that the gain in the direction to 14,000 ft is $(0.7)^{(2/4)} = 0.83$ of the gain along the main axis. Hence 1585 can be replaced by about $1585 \times 0.83 = 1315$. Inserting the appropriate quantities into Equation (3) yields, at 82 nm = 1.52×10^7 cm and $\lambda = 50$ cm,

$$C_{\min} = \frac{2(4\pi)^3 (1.52 \times 10^7)^4 \left(4 \times 10^{-15}\right)}{(50)^2 (1315)^2 (500{,}000)} = 392 \text{ cm}^2 \qquad (4)$$

Because of the uncertainties in some of the quantities which went into this calculation the minimum cross-section of 392 cm^2 must be considered an approximation to the true value. However, it probably would be correct to say that the cross-section would have to be at least several hundred square centimeters for detection at 82 nm. This can be compared with the cross-section of a typical bird which might be flying at the time of the DST is 1–10 cm^2. A flock of birds could have the required cross-section. Of course, if there were a flock of birds very close to the Argosy aircraft during any part of the DST one would expect that the flock would not just suddenly appear and then disappear. It would have been detected both before and after the DST.

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