ANALYSIS OF "UAP" IMAGES IN TWO VIDEOS OBTAINED DURING THE EL BOSQUE AIR SHOW OF NOVEMBER 5, 2010

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ABSTRACT

Videos taken during an air show south of Santiago, Chile (El Bosque) show unexpected dark objects, designated herein as "UAP" (unidentified aerial phenomena), flying through the sky as the airplanes passed by. These UAP objects made mostly small images, sometimes just tiny dots (dark against the background). In a few frames of video the images are large enough to show "structure." These latter images have dark bottoms and sometimes bright tops. Sometimes the dark dots appear in a short series of video frames as if they were flying through the field of view at high speed at the same time that air show airplanes were flying through the sky. Although there may have been several videos by several witnesses that contain these images, portions of only two have been selected for analysis and are considered to be representative of all of them. It was initially thought that the same object had appeared coincidentally (at the same time) in both videos thus allowing for the possibility of a triangulation calculation to determine distance. Once the distance was known the size could be estimated from the image size. The two videos were searched in order to locate a coincidental appearance of UAP. Unfortunately, there was no coincidence of the same object appearing in the two videos at the same time so a triangulation was not possible. Without further information that would show the objects were distant and hence large, it must be considered most likely that the objects were small and nearby such as insects.

INTRODUCTION

During the November 5, 2010, air show in the El Bosque region south of Santiago, Chile, videos of the participating aircraft were made by many different witnesses. Several of these videos show unexpected dark (sometimes with a bright top) images of objects that appear to have flown through the fields of view of the cameras as the planes approached, passed by and departed. The unexpected images in two sections of two of these videos are discussed in depth in the following sections of this article.

The question arose, just what caused these unexpected images? An obvious suggestion was that the objects were small and nearby, which would mean that they could be insects. On the other hand, the provocative image shape and brightness structure (the dark bottom and sometimes a bright top) of the largest images suggested something far more bizarre. Could it have been large and distant and possibly a “UFO” or “flying saucer?”

Image size in a camera is a function of the focal length, the size of the object being photographed/videoed and the distance of the object: I = F (O/D), where I is the image size, F is the focal length, O is the object size (as measured perpendicular to the line of sight from the camera to the object) and D is the distance. Of importance here is the ratio O/D: without knowing either O or D one can determine only the ratio from the photographic data. Hence a particular value of O/D could indicate a small object nearby or a large object that is distant (e.g., a 1 cm object at 1 m makes the same ratio as a 10 m object at a kilometer) The way to determine whether or not the object is nearby and small or distant and large is to perform a triangulation, but this requires that the object be videoed from two locations at the same time This investigation was carried out with the hope that at least two videos would provide image data that would allow for a triangulation and subsequent calculation of distance and size. Unfortunately, the two most promising videos did not show the same object at the same time from two locations.

This article consists of two chapters, each consisting of several sections. Chapter 1 presents an in-depth analysis of UAP that appear in the initial portions of the two videos, herein referred to as H1 and H2, as the Halcones flying team airplanes approached the airfield. Chapter 2 presents an analysis of UAP that appeared in later portions of H1 and H2 as the Halcones airplanes departed from the area (after flying over the airfield). The H in H1 and H2 refers to the Halcones. (Note: there were also UAP recorded as other aircraft flew over the airfield. These are not discussed here.)

CHAPTER 1
UAP AS THE AIRPLANES APPROACHED

PART 1: ANALYSIS OF THE “HALCONES 1” VIDEO

SECTION 1: CALIBRATION OF THE ANGULAR SIZE OF IMAGES USING GEOGRAPHIC FEATURES

The Halcones 1 video was obtained by a witness who used a Canon camera (Powershot 85; 4 MP) that recorded images at a frame rate of 10 per second using a NTSC standard spatial resolution of 640 by 480 pixels. It shows some unexpected images of an object or objects (UAP) silhouetted against the sky. On a frame-by-frame basis it or they appear to cross the camera field of view at a high rate of speed. The largest image is bright on top and dark on the bottom consistent with being opaque (blocking the sky background) and reflective on top.

In order to estimate actual size of an object based on the size of an image of the object it is first necessary to determine the angular size scale of images appearing in the video field of view. The scale factor should be in degrees or radians per pixel (1 degree = 0.0174 radians or 57.3 degrees per radian).

The location is the El Bosque airfield where the cameraman was standing and looking generally northward. Fortunately, there are mountain peaks in the scene, as shown in Frame 7 of the video, that can be used for the angle calibration.

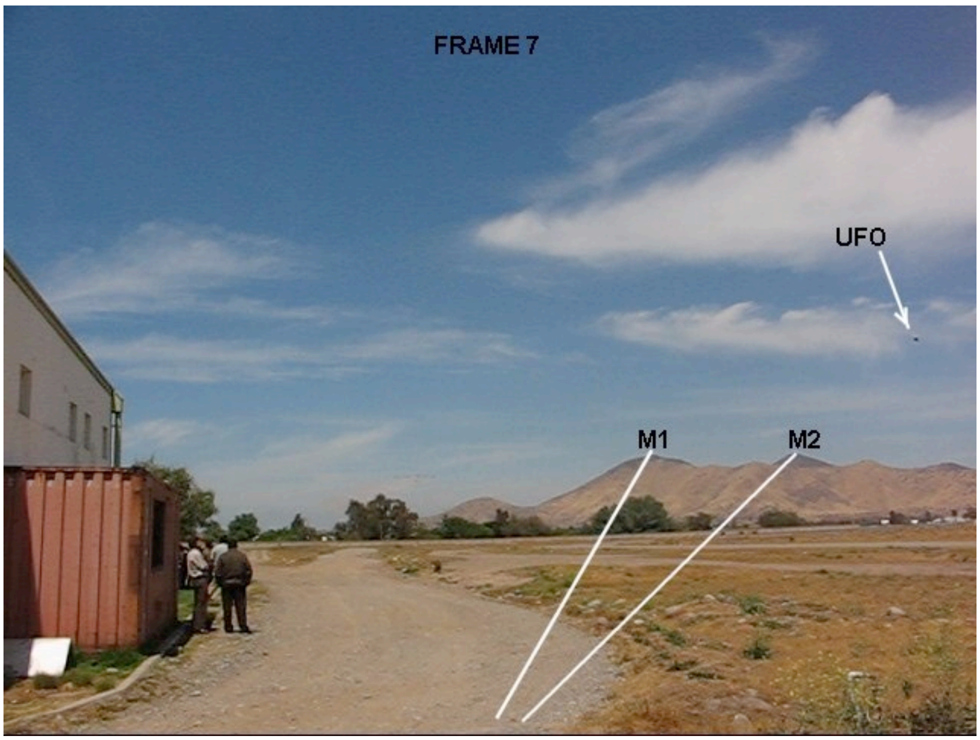

FIGURE 1: H1 VIDEO FRAME 7

The Google Earth imagery of the area is sufficiently detailed as to show the "exact" location of the camera by comparing with the overhead view provided by Jose Lay.

FIGURE 2: OVERHEAD VIEW FROM JOSE LAY: CAMERA AT RED STAR

From the point of view of the camera, the prominent mountain peaks are M1 at azimuth 231.5 deg and M2 at azimuth 239.6 deg so the angle between them is 8.1 degrees.

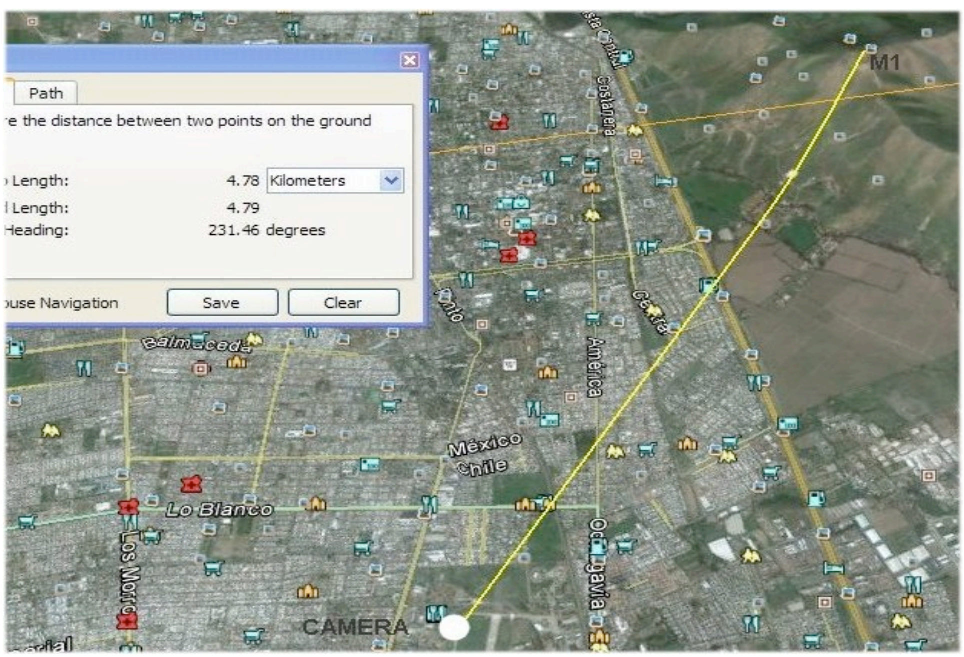

FIGURE 3: GOOGLE EARTH: CAMERA TO M1 (diagonal yellow line)

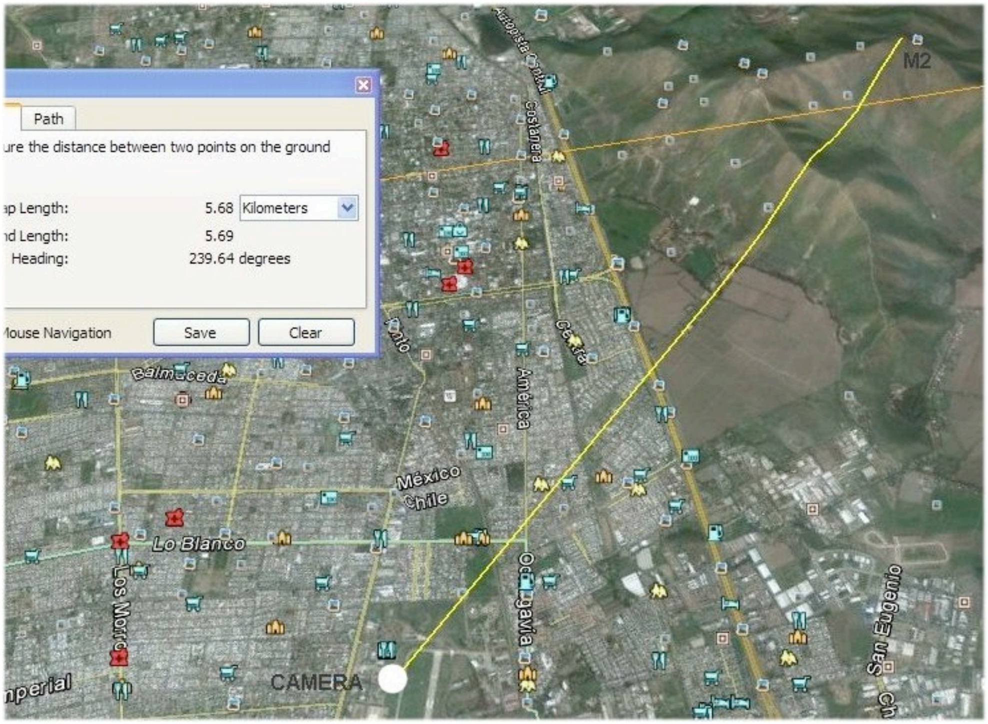

FIGURE 4: GOOGLE EARTH: CAMERA TO M2 (diagonal yellow line)

The spacing in pixels between the images of the peaks of M1 and M2 is 94 at the beginning of the video and about 100 at 11 sec just before the mountains go out of the field of view as the camera rotates to the right. Not knowing which is correct I take the average and use 97 pixels which correspond to 8.1 degrees or about 0.084 deg per pixel (written as 0.084 deg/pix). It is convenient to convert the angle to radians (rad) because the size of a distant object, as measured perpendicular to the line of sight, is approximately the product of the distance times the angular size in rad. (This approximation is quite good for angles less than 35 deg.) There are 0.0174 rad per deg so (0.084 deg/pix) x (0.0174 rad/deg) = 0.00146 rad/pix. This is the needed angle calibration factor.

SECTION 2: RELATIVE SIZES AND DISTANCES OF THE UFO IF THERE WERE NO MOTION BLUR

FIGURE 5: UFO IMAGE IN FRAME 9

At its largest the UFO image is about 12 pixels wide. (Note that the pixilation of the image has been blurred in this Microsoft WORD document presentation making the image appear “smoother” or less “blocky” than it actually is.) Because the UFO was moving to the left, and because it “takes time” to make the picture (the exposure time, herein referred to as “Te”), some fraction of the width of the image is motion blur. This blur appears as a diffuseness or decreased contrast with the background at the left and right edges of the image. The exposure time according to the camera EXIF data was Te = 1/2000 sec. Such a “fast shutter” would minimize but not eliminate the amount of motion blur.

The calculation of object size from image size can be illustrated with a simple example. Assume, for simplicity that Te = 0 in which case there would be no motion blur. In this case the angular width of the UFO image would be about (12 pix) x (0.00146 rad/pix) = 0.0175 rad (the image angular width). If the distance were known one could calculate the object size from this angular size. The actual distance is not known, but to illustrate the calculation we can assume a distance and calculate the size. For example, if the object were 1,000 ft away, 0.0175 rad would correspond to a size given by the product of the distance times the angular size: (1,000 ft) x 0.0175 = 17.5 ft. (As a check note that 17.5 ft/1000 ft = 0.0175 rad) or if it were at 1 km the size would be 17.5 m. Conversely, one can assume a size and calculate a distance. For example, if it were 30 ft in diameter it was 30/0.0175 = 1,710 ft distant. If it were 30 m in diameter, its distance was about 1.7 km. If we assume it was small, say a 1 inch object (bug), it would have been about 57 inches or 4.8 ft distant and a 1 cm object would be 57 cm or 0.57 m distant.

SECTION 3: THE THEORY OF MOTION-BLURRED IMAGES

(The following paragraphs describe how motion blur affects an image and how to estimate what portion of the image is due to the actual angular size of an object and what part is caused by blur. Any reader familiar with this may want to skip to the next section.)

The preceding calculations of size or distance were done to illustrate the results when Te is zero so that there would be no motion-caused blur of the image. Of course, Te did not equal zero. Therefore, since the object apparently moved a considerable distance between frames (see below), it is logical to assume that it did move some amount during the exposure time, in which case the total width of the image is “too large.” The problem then is to determine what fraction of the image width is due to motion blur and what fraction is due to the angular width of the object itself.

The angular distance over which blur occurs, herein called the **blur angle** or Ba, in radian measure, is the product of the **angular speed**, Sa,p, measured in rad/sec, multiplied by the exposure time, Te. Here Sa,p is the component of object angular speed or velocity that is **perpendicular** to the line of sight. Therefore,

$$Ba = Sa,p \times Te, \text{ rad} . \qquad 1)$$

Thus, if Te were zero, Ba = 0. For any real exposure time there must be some blurring of the left and right edges due to the motion transverse to the line of sight. Suppose, for example, that the angular width of an object is Wa. Suppose that an object that moved 1/10 of its own width during Te. Then this object moved 1/10 of its angular width, 0.1Wa, during the exposure time. That is, Ba = 0.1Wa and the relative angular blur size is Ba/Wa = 0.1 = 10%.

Consider the image of a solid, dark object that appears rectangular with the width and height lying in a vertical plane perpendicular to the line of sight from the camera to the object. Assume the horizontal width of the object, left to right, is called Wo, measured in m or ft. Assume this object is viewed along a line, D, that is the horizontal distance from the observer to the rectangle and is also perpendicular to the width of the rectangle. The angular width, Wa, in radians is given by

$$Wa = Wo/D, \text{ in rad} \quad \text{(useful approximation for angles less than 35 deg or 0.6 rad)} \qquad 2)$$

Suppose that the actual speed component perpendicular to D is Sp. The angular speed of the object as measured perpendicular to the sighting line is

$$Sa,p = Sp/D, \text{ in rad/sec}, \qquad 3)$$

(Note: in calculations below D is replaced by D9.) Assume the object is traveling at angular speed $S_{a,p}$ (rad/sec) perpendicular to the line of sight, D. Imagine it to be at some initial location along its travel path at the beginning of the exposure and imagine that during the exposure it moves an angular distance $B_a = S_{a,p}T_e$ (in rad) . Then both the left and right vertical edges of the rectangle (edges that are perpendicular to the motion) have moved an amount equal to the angular distance Ba. Hence the **total angular width** of the blurred image obtained during time Te, written as $W_{a,t}$, measured from the "beginning" of the left (right) edge of the blurred image to the "end" of the right (left) edge of the blurred image is the sum of the unblurred angular width, Wa, plus twice the angular blur distance, $B_{a,p}$:

$$W_{a,t} = W_a+2B_{a,p} = W_a + 2S_{a,p}T_e, \text{ in rad.} \qquad 4)$$

Thus, if it moved 10% of its own length so that $B_{a,p} = 0.1\ W_a$, then the total angular image width would be $W_{a,t} = W_a+2(0.1W_a) = 1.2W_a$ rad which is 20% larger than it would be if $T_e = 0$. The **fraction** of the image due to the object alone is

$$W_{o,f} = W_a/(W_{a,t}) \qquad 5)$$

and the fraction of the image due to motion alone, the **blur** fraction, is

$$W_{b,f} = 2B_{a,p}/W_{a,t}. \qquad 6)$$

An image of this moving rectangle would have diffuse left and right edges. The contrast between the image and the background would be low or zero at the left and right outer boundaries of the blur distance. The contrast is not constant within the blur region. Instead, it increases as one moves from either the left or right outer edges of the blur region toward the center of the image.

Note that motion-induced blur affects the edges that are perpendicular to the motion. Edges of the rectangle (or object) that are parallel to the motion are not blurred. This difference in blurring of the edges differentiates motion blur from the effects of imperfect focus which (in a camera corrected for astigmatism) affects all edges the same way. (However, if an object were traveling toward or away from a camera all edges would be blurred by motion. That isn't the case here.)

Of course, there are cases in which Ba is much larger than Wa. These cases typically lead to very diffuse object "tracks" if the object were opaque and seen against a daylight background, or to long streaks or bright line images if the object is a light photographed against a dark background (often the situation when a hand-held camera is used to photograph a bright light, star, planet, etc.)

SECTION 4: BLUR ESTIMATE FOR THE H1 VIDEO IMAGE

In this H1 case the **angular** size of the portion of the image due to motion blur, Ba, seems to be less than the unblurred angular width, Wa. The object is seen against the background of a bright blue sky and the left and right edges seem to be blurred but it is difficult to determine the width of the blur because the total image width is small, about 12 pix wide.

It will be shown below that the *frame-to-frame* motion that is consistent with the video images actually predicts the amount of blur to be expected. However, as a first guess at the result, it appears from inspection of the image (see above) that 40% or more of the total image width is due to blur (this is only a visual estimate!). That would leave 60% for the actual width. Assuming this to be true the estimated image width, Wi, of the **image** of the object, in pixels, is Wi,pix = (60% of 12) = 0.6 x 12 pix = 7.2 pix. The blur occurs at the left and right edges and the left and right edges each have the same amount of **blur image** width, Bi,pix = (12 – 7.2)/2 = 4.8/2 = 2.4 pix. Using the angle calibration that was presented above, 0.00146 rad/pix, the unblurred **angular** width of the UFO itself, **perpendicular** to the sighting line, is estimated to be Wa = (7.2 pix) x 0.00146 rad/pix = 0.01 rad and the **angular** distance of blur **perpendicular** to the sighting line is Ba,p = 2.4 pix x 0.00146 = 0.0035 rad. The **total** angular image width is (see below) Wa,t = Wa + 2Ba,p = 0.01 + 2 x 0.0035 = 0.17 which is close to the value mentioned above, 0.0175 corresponding to 12 pixels.

With this estimated value for the angular size of the object, Wa = 0.01 rad, the object distance, D, can be calculated once an actual object size, Wo, is assumed. For example if Wo = 1 inch the object would be

$$Wo/Wa = (1 \text{ inch})/.01 = 100 \text{ inches} = 8.3 \text{ ft from the camera.} \qquad 7)$$

Similarly, a 1 ft object would be (1 ft)/0.01 = 100 ft from the camera and if 1 m in size it would be 100 m from the camera and so on.

SECTION 5: APPARENT MOTION OF THE OBJECT

The frames of the video that are of interest here are frames 7 - 9 and 43 – 46. Frame 7 has already been presented (see above). Below are the other frames of interest.

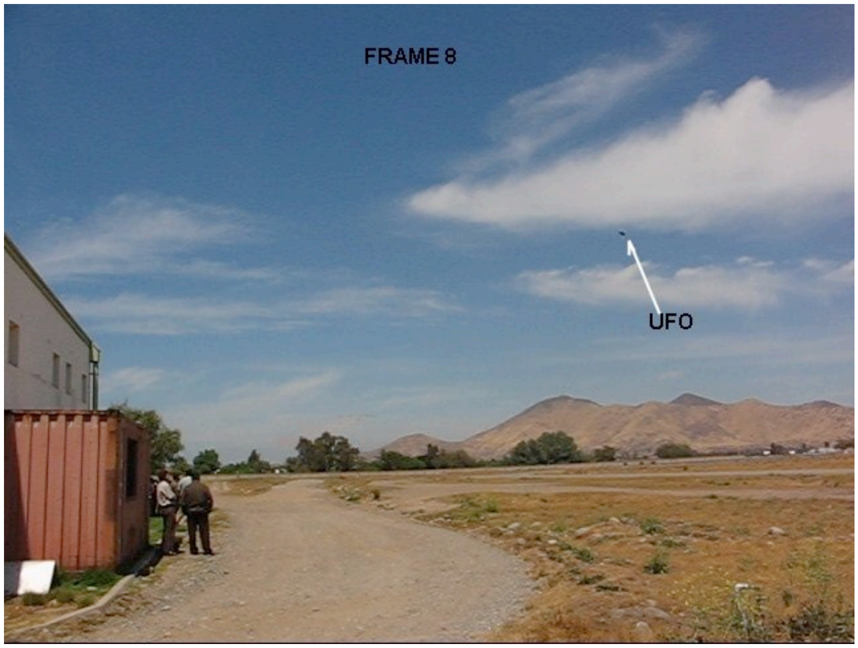

FIGURE 6: H1 VIDEO FRAME 8

FIGURE 7: H1 VIDEO FRAME 9

FIGURE 8: H1 VIDEO FRAME 43

FIGURE 9: H1 VIDEO FRAME 44

FIGURE 10: H1 VIDEO FRAME 45

FIGURE 11: H1 VIDEO FRAME 46

The following discussion is based on a "crucial" assumption that may not be true, specifically, that the object in frames 43 – 46 is the same as the object in frames 7, 8, and 9. Unfortunately there is no way to prove this, but the similarity in shape and brightness structure makes this at least a good starting assumption.

A study of the UFO image positions using the fundamental assumption that image size is inversely proportional to distance and that the object was of constant size will show that the object followed a loop trajectory (assuming each image is of the same object!). It approached from the right (see frame 7), traveled to the left (frame 8) and went out of the field of view after frame 9. Then, a few seconds later, it reappeared at the left (frame 43) and farther away and traveled to the right and out of sight (frames 44, 45, 46). The Table below shows the variations in image size and the variations in the brightness level of the darkest pixel in each image, after converting each image to grey levels (color removed leaving only 255 brightness levels within the picture). To illustrate the effect of removing color the grey scale version of frame 9 is shown below.

FIGURE 12: H1 FRAME 9, GREY SCALE

TABLE 1
IMAGE PIXEL SIZE AND RELATIVE BRIGHTNESS
OF DARKEST PIXEL IN UFO IMAGE

Frame # (10 fr/sec)	Total Width in pixels	Relative Brightness of darkest pixel (0 = black, 255 = white)	Relative Brightness of surrounding sky
7	5	25	120-140
8	6	20	100-120
9	12	13	75-85
43	9	53	100-125

44	5	72	115-120
45	6	79	135-140
46	5	98	135-140

It should be noted that these pixel width numbers are estimates because sometimes it is difficult to determine where the edge of an image is. (Other investigators looking at the same images might claim the pixel sizes are different by a pixel or two.) The image size first increased and then decreased, with the largest image in frame 9. Since image size (for a constant sized object) is inversely proportional to the distance from the camera to the object (smaller distance, larger image) the pixel width data suggest that the object was closest to the camera in frame 9. Comparing the largest image width with the smallest one finds a ratio of 12/5 = 2.4, which suggests that at its farthest the object was more than twice as far as at its closest.

The variations of the brightness levels of the darkest pixels of each UFO image also are consistent with the idea that the object approached and receded. This is because the brightness of an image of a dark surface of any object (e.g., the bottom of the object, not lighted by the sun) is lowest (darkest) when it is close. The brightness of the dark surface increases with distance, eventually approaching the brightness of the horizon. Looking at the tabulated data one sees a brightness decrease to frame 9 followed by a brightness increase to the last frame. Part of this brightness variation results from variations in the sky brightness close to the object, but most of this brightness variation is consistent with an approach followed by a recession of the object. Hence it is reasonable to conclude that the object did follow the track or path as suggested by the video images.

SECTION 7: ESTIMATE OF THE IMAGE SIZE RATIO AND DISTANCE RATIO USING FRAMES 8 AND 9

The object changed position between frames, which are 0.1 sec apart, by rather large angles indicating a considerable angular speed. Since the distance to the object is not known it is necessary to assume either a distance or an object size such that the ratio Wo/D is consistent with the closest (largest) image. What follows is an analysis of the data contained only in frames 8 and 9 since these show the largest images that are separated by a known time (0.1 sec) .

In frame 8 the UFO is at image plane coordinates X = 465 pix (measured horizontally from the left) and 172 pix (measured vertically downward from the top). The image of the distant ground (or the base of the mountain) below the object is at 340 pix down from the top so the angular elevation above (approximate) horizontal was about (340 - 172) = 168 pixels or 0.245 rad = 14 degrees above horizontal.

In frame 9 the UFO is at X,Y = 151,88 and, using the head of a man standing at a distance from the camera as a reference for horizontal, the UFO was about (350 - 88) = 262 pixels or 0.38 rad = 22 degrees above horizontal

The camera rotated a small amount between frames and that would make a small, unimportant correction to the following calculation of distance traveled.

An estimate of the distance traveled by the object between frames 8 and 9 is based first on the "delta X" value, 465 - 151 = 314 pix or 314 x 0.00146 = 0.46 radians. This is a measure of the horizontal distance traveled as projected onto a plane parallel to the camera focal plane (i.e., projected onto a plane perpendicular to the line of sight). The angular elevation also changed - increased - by 172-88 = 84 pixels or .059 radians. It could be that the UFO actually changed its altitude by some amount, but the increased angular elevation was at least partially a result of the object getting closer to the camera. (Even if an object travels at a constant altitude toward an observer on the ground its angular elevation, as seen by the observer, increases.)

In frame 8 the total image width angular size, Wa,t, is estimated to be 6 pix and in frame 9 it is about 12 pix. The ratio is about 1:2. Let D8 be the slant distance from the camera to the object in frame 8 and D9 be the distance in frame 9. The distance ratio, D8/D9, is the inverse of the image size ratio, i.e., D8/D9 = 12/6 = 2 which means that the distance in frame 9 was about half of that in frame 8: D9/D8 = 1/2. (Note: the use of the total image width in this image size ratio is based on the assumption that the component of the speed perpendicular to the line of sight stayed constant so that the amount of blur was the same percentage at both distances.)

The angular height, E, changed from 0.24 rad to about 0.38 rad. Let DN be the slant distance from the camera to the UFO and H is its height where N = 8 or 9. Then H/DN = EN, where E is the elevation in radians as long as the angle is small enough so that sin E is approximately equal to E in radians. (This approximation is reasonably good for angles below 30 deg or 0.52 radians.) In this case we have two angular elevations, E8 and E9. For the first, H/D8 = E8 and for the second, H/D9 = E9. Assume level flight so that H is constant. Then H = (D8)(E8) = (D9)(E9). Solving this equation for the distance ratio we have D8/D9 = E9/E8 = 0.38/0.24 = 1.6. This is smaller than the distance ratio calculated from the image size and suggests that the object may have decreased its elevation by some amount as it traveled from its location in frame 8 to its location in frame 9.

It is a sufficiently good approximation to treat the triangle made by the camera location, the location in frame 8 and the location in frame 9 as a triangle lying in a somewhat tilted plane. Despite the tilt of the triangle it is sufficiently accurate to treat the triangle as if it lay in a horizontal plane and to calculate the angle between the sighting lines along D8 and D9 using the difference between X positions, 314 pix or 0.46 rad, which is approximately 26 deg.

SECTION 8: ESTIMATE OF THE DISTANCE TRAVELED DURING THE TIME BETWEEN FRAMES

In order to determine the speed of the object it is necessary to find the distance, D, defined in the diagram below, that the object traveled during a single frame time, Tf = 0.1 sec. Since no actual distances are known this distance will be calculated as a function of D9. In other words, D depends upon the value of D9 and D9 depends upon the assumed object size, Wo, and the measured angular size, Wa, through the relation given above, D9 = Wo/Wa, where Wa is estimated to be 0.01 rad based on inspection of the image.

The law of cosines is used as follows to find the straight line distance between the UFO locations from the measured ratio D8/D9 and the angle between the sighting lines. The geometry is illustrated below where the triangle represents the distances as viewed from above:

D^2 = square of the distance between UFO locations in frames 8 and 9 (assumed to be a straight line) 8)

$= (D8^2 + D9^2 - [2 \times D8 \times D9 \times \cos C])$ where D8 = 2 D9 and C = 26 deg.

Substituting 2D9 for D8 we have:

$$D^2 = D9^2 \times (2^2 + 1 - [2 \times 2 \times 1] \times \cos 26) \qquad 9)$$

$$= D9^2 \times (5 - [4] \times 0.90)$$

$$= 1.4\ D9^2 \qquad 10)$$

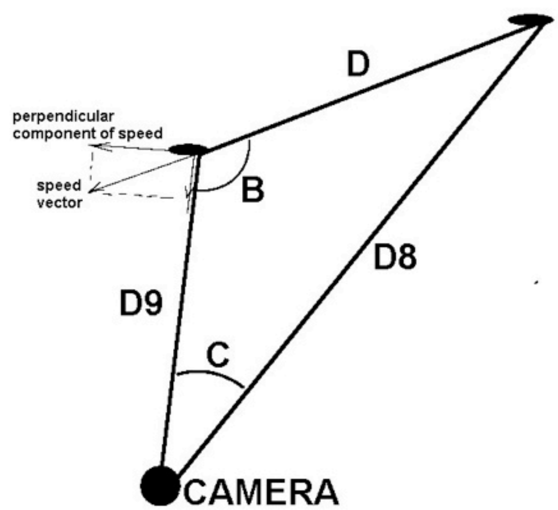

FIGURE 13: DISTANCES USED IN CALCULATION

Finally, after taking the square root of both sides,

$D = 1.18\ D9 \qquad [= 1.18\ Wo/Wa = 118Wo$ since $Wa = 0.01]$. 11)

(If $D8 = 1.6\ D9$, as suggested by the angular elevation ratio, $D = 0.82D9$)

If the above assumption of straight line motion between locations is at least approximately correct and if the 2:1 image width ratio is approximately correct, the UFO moved from right to left across the field of view by a distance that was 1.18 times its closest distance. This happened during the frame time, Tf = 0.1 sec, according to the video (viewed using Quicktime). (Note: if the object flew in a curved path it traveled farther, and therefore faster, than calculated here.) Thus, its speed, with the above straight line and constant speed assumptions, was

$S = D/Tf = (1.18D9)/Tf = 1.18D9/(0.1 \text{ sec}) = 11.8\ D9$, m/sec or ft/sec, 12)
(If $D8 = 1.6\ D9$, $S = 8.24D9$)

Thus, if D9 was 1 m (corresponding to Wo = 1 cm and Wa = 0.01 rad), it moved at 11.8 m/s or 42 km/hr, and so on for other assumed distances.

The speed just calculated is not perpendicular to the line of sight along D9. To find the perpendicular component, Sp, it is necessary to use another trigonometric equation in order to find angle B. This is done using the "law of sines" as follows:

$$D / \sin C = D8 / \sin B \qquad 13)$$

Solving for B, with D = 1.18 D9, D8 = 2D9 and C = 26 deg

$$B = \text{ARCSIN}\,[(2D9 \sin 26)/1.18D9] = \text{ARCSIN}[2D9 \times 0.438/1.18D9]$$
$$= \text{ARCSIN}[0.74] = 48 \text{ deg} \qquad 14)$$

(If D8 = 1.6D9, B = 58.2 deg

The resulting angle, 48 deg, is the acute angle with this value (0.74) of the sine. However, the actual angle is "obtuse" (greater than 90 deg). The obtuse angle with the same value of the sine is 180 – 48 = 132 (i.e., sin 132 = 0.74).

The illustration above shows that the speed vector is "projected onto" the direction perpendicular to D9 by multiplying the speed by the sine of the angle between the speed vector, S, and D9. This angle is 180 – 132 = 48 deg. Therefore the "projection factor", Fp = sin(48) = 0.74, and

Sp = perpendicular component of the speed vector
= SFp = S sin(48) = S(0.74) or 0.74 S. 15)

(If D8 = 1.6D9 the angle is 58.2 deg and SFp = S sin(58.2) = 0.85 S.)

This calculation assumes the UFO traveled at a constant speed and direction along D, and that the speed was the value estimated above to be 11.8 D9 which would be in ft/sec or m/s. Therefore at the location in frame 9 the speed component perpendicular to the sighting line D9 is

$$Sp = Fp(1.18D9)/Tf = 0.74 \times 11.8D9 = 8.7D9, \text{ in m/sec or ft/sec.} \qquad 16)$$

(If D8 = 1.6 D9, Sp = 0.85 x 6.1D9 = 5.18D9)

Since the exposure time was Te = 1/2000 sec, the distance traveled during the exposure time was the blur distance perpendicular to the line of sight, Bd, given by

$$Bd,p = SpTe = 8.7D9\ Te = 0.00435D9 \text{ in m or ft.} \qquad 17)$$

and the angular blur is (dividing by D9)

$$Ba,p = Bd,p/D9 = 0.00435 \text{ in rad} \qquad 18)$$

(If D8 = 1.6D9, Ba,p = 0.0026.)

Since both the left and right edges moved by that amount, the total angular blur was 2 x 0.00435 = 0.0087. Thus the total angular image width is therefore predicted to be

$$Wa,t = (Wa + 2Ba,p) = Wa + 0.0087 \text{ in rad.} \qquad 19)$$
$$(\text{If } D8 = 1.6\ D9,\ Wa,t = Wa + 0.0052.)$$

Introducing the initially estimated value of Wa, Wa = 0.01 rad, we have

$$Wa,t = 0.0187 \qquad 20)$$
$$(Wa,t = 0.0152)$$

From this we have the fractions as defined in equations 5 and 6 above for the fraction of the image width that is due to the object,

$$Wo,f = Wa/(Wa,t) = 0.01/0.0187 = 0.53 = 53\% \qquad 21)$$
$$(Wo,f = 0.01/0.0153 = 0.65 = 65\%.)$$

and the fraction of the image width due to the distance the object traveled (the blur distance) during the exposure

$$Wb,f = 2Ba,p /Wa,t = 0.0087/.0187 = 0.46 = 46\% \qquad 22)$$
$$(Wb,f, = 0.0053/0.0153 = .35 = 35\%)$$

It should be noted that these values are close to the initial assumption that about 60% of the image width is due to the object itself and 40% of the width of the UFO image was motion blur. However, the calculation has predicted a total image size of 0.0187 rad whereas the measured total width is about 0.0175 rad (see the above calculation that was done under the assumption of no blur). The implication of this result is that the calculated speed was too great.

It is important to note that the angular blur distance, Sa,pTe, does not depend upon the assumed object size or object distance. If the angular blur is multiplied by a distance from the camera to the object the result is the perpendicular distance traveled during the exposure time. Thus we could assume a distance and calculate how far the object traveled during the exposure time and then solve for the speed.

In this analysis the calculations of distance are based on the assumed actual width of the object, Wo, rather than on an assumed distance, D9, to the object in frame 9. To estimate speed requires an assumption of the actual angular size of the object, Wa, which in the above discussion was estimated at 60% of the angular image width at its closest in frame 9. This size was 7.2 pix corresponding to 0.01 rad in angular width. The distance of the object with angular width Wa is calculated according to the equation, D9 = (Wo)/0.01. Thus we can create the following table using metric units:

TABLE 2
CALCULATED DISTANCE AND SPEED
FOR VARIOUS OBJECT SIZES

Assumed actual Width, Wo, m	Corresponding distance D9 = Wo/Wa, m	Estimated speed (from equations12-16) Sp = (0.74)1.18D9/0.1 = 8.7 D9 in m/sec		Fraction due to blur Wb,f = 2Ba,p/ Wa,t

For Wa = 0.008 rad and D8 = 2D9

Width, Wo, m	D9=Wo/.008 = 125 Wo, m	Sp = 8.7D9 = 1087 Wo, m/sec		2(8.7)(1/2000) = / .008+0.0087
0.005 m (5 mm)	0.625 m	5.4 m/sec		0.52 = 52%
0.01 m (1 cm)	1.25 m	10.87 m/sec	(39 km/hr)	0.52
0.1 m	12.5 m	108.7 m/sec	(390 km/hr)	0.52
1 m	125 m	1987 m/sec	(3900 km/hr)	0.52
10 m	1250 m	19,870 m/sec		0.52

For Wa = 0.01 and D8 = 2D9

Width, Wo, m	D9=Wo/.01 = 100 Wo, m	Bd,p = 8.7D9 8.7(100Wo) = 870 Wo, m/sec		Wb,f = 2Ba,p/Wa,t 2(8.7)(1/2000) / .01+0.0087 = . 0087/.0187
0.005 m (5 mm)	0.5 m	4.3 m/sec	(15.5 km/hr)	= 0.46 = 46%
0.01 m (1 cm)	1 m	8.7 m/sec	(31 km/hr)	0.46
0.1 m	10 m	87 m/sec	(310 km/hr)	0.46.
1 m	100 m	870 m/sec	(3100 km/hr)	0.46
10 m	1000 m	8700 m/sec	(31,000 km/hr)	0.46

For Wa = 0.012 rad and D8 = 2 D9

0.005 m	0.417 m	3.6 m/sec	0.42 = 42%
0.01 m	0.83 m	7.2 m/sec	0.42
0.1 m	8.3	72 m/sec	0.42
etc.	***etc.***	***etc.***	***etc.***

For Wa = 0.013 rad and D8 = 2D9

0.005	0.38 m	3.3 m/sec	0.40 = 40%
0.01	0.77	6.7	0.40
0.1	7.7	67	0.40
1	77	670	0.40

The table above shows, for an estimated value of angular size, Wa, the way the distance and speed vary with the assumed object size, Wo. The table also shows how the speed varies with Wo and Wa when the speed is calculated using the theoretical expressions above for Sp (equations 12 and 15). It also shows how the blur fraction varies with estimated object angular width. When Wa is chosen to be 0.013 rad, which is about 30% larger than the initially "guessed-at" angular size (Wa = 0.01 rad), the fraction of the image size due to motion blur becomes equal to the initially guessed-at value, 40%. The angular size 0.013 rad corresponds to an image pixel width of 013/.00146 = 8.9 or 9 pixels whereas the guessed-at 0.010 rad corresponds to 7.2 or 7 pixels.

Unfortunately this analysis does not provide an actual size or speed of the object. That means that it doesn't allow for a complete test of possible explanations. It has been suggested that the speed was very high, say 6000 mph or 8800 ft/sec = 2680 m/sec. Such a large speed would imply a large object, as will be shown.

Suppose the speed were 8800 ft/sec (the speed component perpendicular to the line of sight). Then the distance the object traveled between frames (0.1 sec) would be on the order of D = 8800 Tf = 880 ft and the blur distance would be 8800 Te = 8800(1/2000) = 8800 x 0.0005 = 4.4 ft. The portion of image width due to motion blur would be 2Bp = 8.8 ft and if this accounted for 40% of the total image width, the total width would be 8.8/0.4 = 22 ft. Sixty percent of the total image width would be the image of the object itself as if unblurred by motion. The object width would then be 0.6 x 22 ft = 13.2 ft. Applying similar reasoning to lower speeds one finds smaller sizes. For example, using 44 ft/sec (30 mph) the blur distance would be 44 x 1/2000 = 0.022 and 2Bp = 0.044 ft = ½ an inch. If this were 40% of the total image width, the total width would be 0.5"/0.4 = 1.25" and 60% of this, the presumed object width, would be 0.75", clearly "bug sized." The distance of such a small object would be less than a meter.

PART 2: A SEARCH FOR TRANGULATION BASED ON THE H1 AND H2 VIDEO UAP IMAGES

SECTION 1: COMPARISON OF THE FIRST FEW SECONDS OF THE TWO VIDEOS

The H1 video by witness 1 has been described above. Anomalous images, interpreted as images of UAP, are found in frames 7, 8 and 9 and again in frames 43, 44, 45 and 46. These frames were taken with a Canon camera with a short shutter time of 0.0005 sec and the time between frames is 0.1 sec. The video begins before the Halcones airplanes are visible and the scenery shows distant mountains and then the oncoming Halcones airplanes.

The Halcones 2 video showing the approaching airplanes (H2, also referred to as the first 30 seconds of "Movo1011.avi) was taken by witness 2 who was 20 – 30 ft east-southeast of witness 1 (exact location not known). He used a Sony videocamera that was somewhat "zoomed in*" (effectively a longer focal length lens)* as compared to the Canon camera of witness 1. Hence the images of distant objects were larger and the field of view was narrower than that of H1. The video frame rate was 25/sec but the storage format for H2 was different than that of H1. In the H1 video each frame is unique, forming a continuous set of images (a new image each 0.1 sec.) In the H2 video, to save memory space, every third image is a repeat of the previous new image, i.e., it uses the

FIGURE 14: CALIBRATION OF THE H2 VIDEO

following format: new frame, new frame , repeat the last frame, new frame, new frame, repeat the last frame, etc. This makes the video "jerky" when viewed on a frame-by-frame basis. Of course, potential video data are lost in this way (every third frame is a repeat of the second so whatever happens in every third frame is not recorded).

The H2 video is sort of a "zoomed in" version of part of H1 with an angular size scale factor of 8.1 deg/306 pix = 0.0264 deg/pix. Converting to radian measure this is 0.00046 rad/pix, which considerably smaller than the 0.00146 rad/pix calibration of the H1 video. The airplane images are, therefore, considerably larger and the field of view is smaller, as shown above in a frame that is 4 seconds into the H2 video.

Because H1 and H2 were taken from different locations there was the hope that the same object would appear at the same time in the two videos, thereby allowing a triangulation to be carried out in order to estimate the distance of the object. If the distance could be estimated by triangulation (or any other method), then the actual size could be determined by multiplying the angular size of the image by the estimated distance (as illustrated in the previous section using assumed distances). One might expect that a triangulation could provide a useful distance estimate as far as 100 times the spacing between cameras *if* the distant object appeared in both videos *at the same time*, and *if* the length and direction of the baseline is known accurately (the baseline is the line between the camera operators), and *if* the directions to the object from the two cameras can be accurately determined (the angle between the sighting line directions to the object from the two cameras, the "parallax," is particularly important). This last requirement can be met if distant land features appear in the field of view of both cameras. At the very least a triangulation should be able to distinguish between a small object nearby (parallax is large) and a very large object far away (parallax is small).

As stated above, triangulation requires, at the very minimum, that the same object be viewed at the same time by two cameras. Hence a search was made of videos H1 and H2 to determine if an anomalous object appeared at the same time in the two videos and, if so, the magnitude of parallax.

The obvious first question to be asked is this: does the object (or objects) of interest that appears in the H1 video also appear in the H2 video? This question was answered in the negative when it was found that the H2 video begins at the time of the 61^{st} +/-1 frame of H1 (the first frame is numbered as 1), i.e. about *6.0 seconds lapsed time after* the beginning of the H1 video (the first frame is considered to be at 0 seconds elapsed time). This was determined by studying the locations of the airplanes relative to the distant mountain peaks. The picture below shows a comparison of the two video images: the H1 image in the 61^{st} video frame and the H2 image in the first frame of the H2 video.

TIME SYNCHRONIZATION BASED ON THE LOCATION OF THE AIRPLANES AS SEEN IN H1 AND H2

FIGURE 15: SYNCHRONIZING THE TWO VIDEOS

The larger format image at the left is from the H1 video. Note that in both images the airplane at the left side of the airplane formation is over the lower, left hand, mountain peak Since the positions of the airplanes change frame by frame and the time between frames is 0.1 sec for H1, the accuracy in comparing the airplane positions is limited to about 0.1 sec. Hence, as stated above, H2 begins 6.0 +/- 0.1 seconds after H1 begins. Unfortunately the interesting imagery in H1 occurs during the first 4.6 seconds, so there is no possibility of a triangulation of the object(s) shown in the initial portion of the H1 video.

A study of the H2 video showed that there is a series of UAP "dark dot object" images that begins in the 44th frame of the H2 video (first frame is labeled 1; in terms of seconds of elapsed time, with the first frame labeled zero seconds, this is 43/25 = 1.72 sec into the H2 video). The following frames show a small image that is noticeably darker than the surrounding sky, a "dark dot" image. These images appear at the left side of the frame and seem to travel toward the upper right in a series of 10 frames. (The dot appears in an eleventh frame, but this eleventh frame is a repeat of the tenth frame so it does not actually show where the "dot" was during the time of the eleventh frame.) The video also shows the oncoming Halcones planes and the mountain peaks below them allowing H2 and H1 to be synchronized, as described above. For example, by comparing the location of the right hand airplane with the mountain peak M1 one finds that the H2 frame at 1.72 sec of elapsed time corresponds 6.0 sec + 1.72 sec = 7.72 +/- 1 sec of elapsed time in the H1 video. Other frames were synchronized by comparing the locations of the airplanes relative to the M1 mountain peak.

The corresponding frames are shown below, with H2 at the left and H1 at the right. Of particular importance for this investigation is the fact that "dark dot objects" that appear in H2 (see arrows) do not appear at all in H1 (at least I have not been able to find dark dots in the corresponding frames of the H1 video). It is to be noted that the cameras were 20 – 30 ft apart and hence a *small* object that was *close to* one camera could appear within its field of view and might *or might not* appear in the field of view of the other camera. (The fields of view overlap at great distances from the cameras but not close to the cameras.)

In the pictures below the arrow in the frame at the left indicates the location of the dark dot in H2. The circle in the frame at the right indicates the area of the sky in the H1 video where the dark dot in the corresponding H2 frame would appear if it were distant and large. The location of the circle was determined by comparing the cloud structure in the frames.

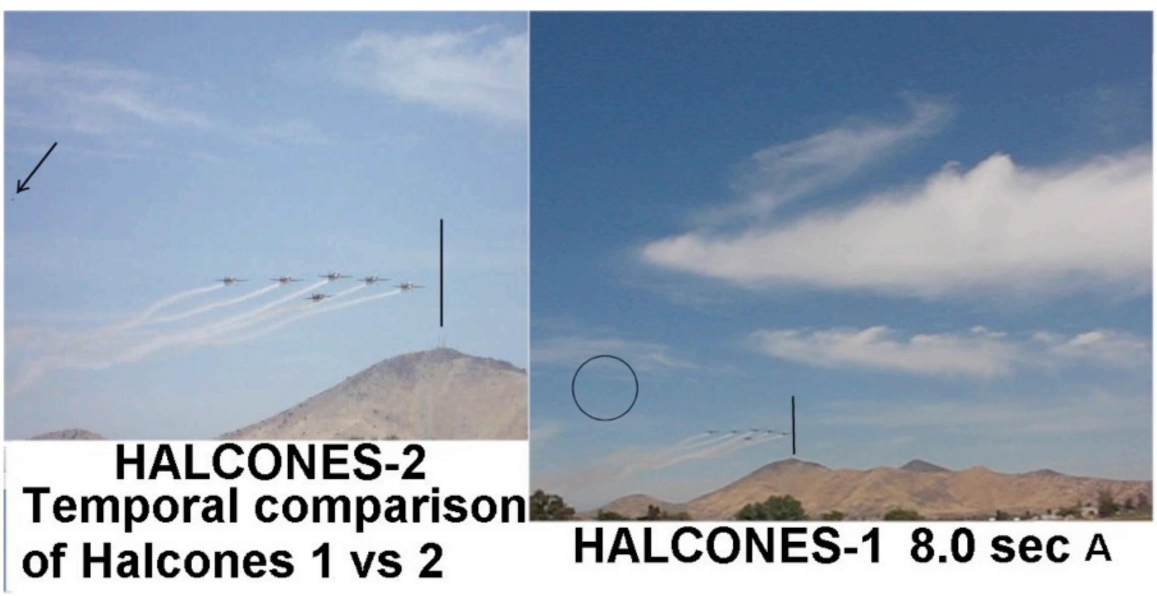

FIGURE 16: COMPARISON OF H2, 44th FRAME, WITH H1, 81st FRAME

The 45th frame of H2 repeats the 44th frame. The 46th frame is not shown here.

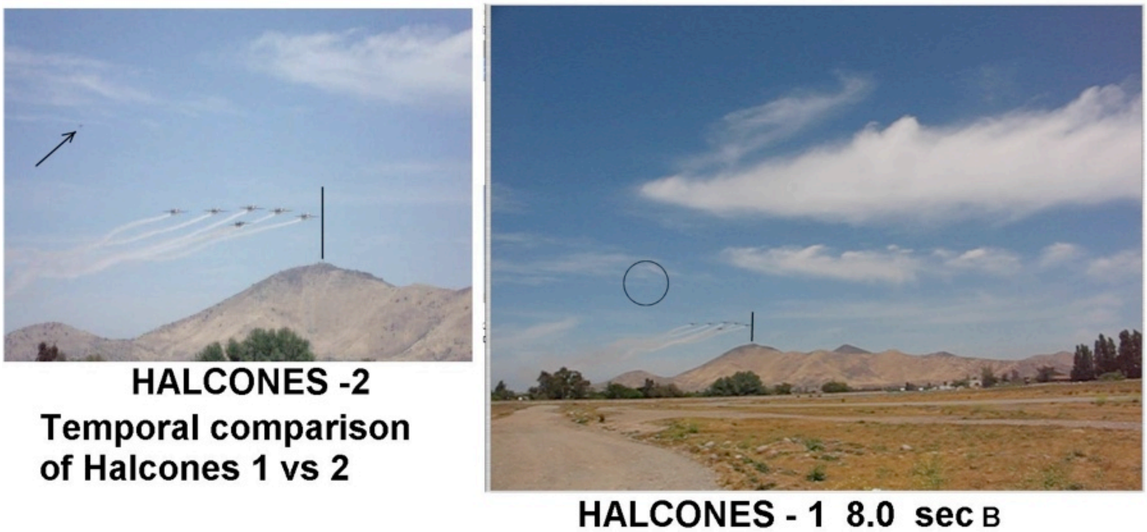

FIGURE 17: COMPARISON OF H2, 47^{th} FRAME, WITH H1, 82nd FRAME

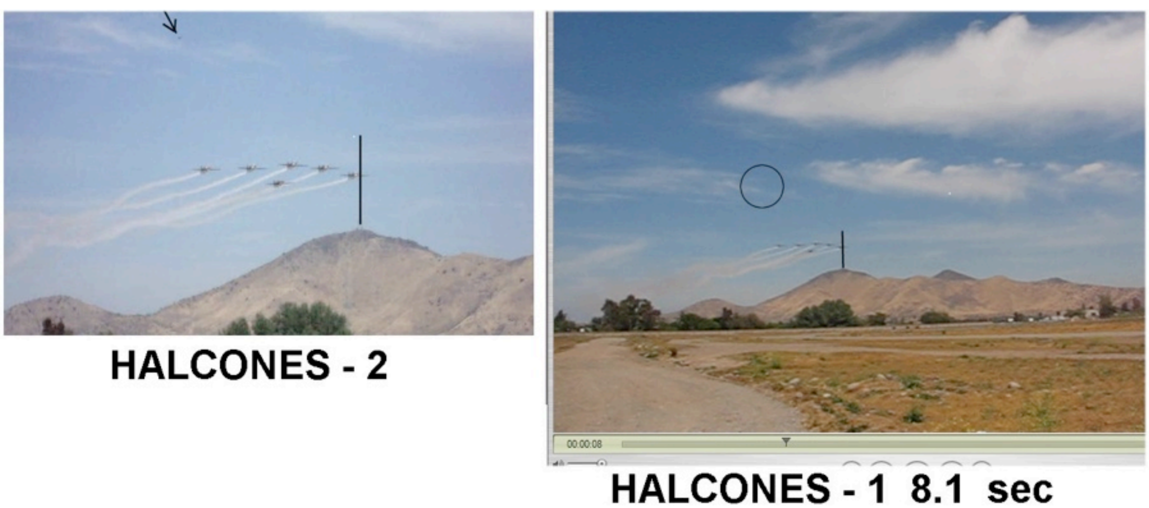

FIGURE 18: COMPARISON OF H2, 49th FRAME, WITH H1, 82^{nd} FRAME

HALCONES - 2

HALCONES - 1 at 8.2 sec

FIGURE 19: COMPARISON OF H2, 49th FRAME WITH H1, 82nd FRAME

HALCONES - 2

HALCONES 1 AT 8.2 sec

FIGURE 20: COMPARISON OF H2, 52nd FRAME, WITH H1, FRAME 82

HALCONES - 2

HALCONES - 1 at 8.3 sec

FIGURE 21: COMPARISON OF H2, 53rd FRAME WITH H1, 84th

If the object were large and far away it should appear in both videos. Because the dark dots that appear in H2 do not appear in H1 (as far as I can determine) there is no proof that the object could not be small and near the H2 camera. In fact, because the cameras were separated by 20 – 30 ft it is logical to suggest that the object was small and within the field of view of the H2 camera but not within the field of view of the H1 camera. (Of course, one might argue that, because the image of the object is a tiny dot in the narrow field of view of H2 it would make an even smaller image in the H1 video, perhaps too small to register as a pixel in H1, i.e. , essentially an invisible image. But if this were true there still would be no triangulation because it would be impossible to triangulate using an invisible image.)

CHAPTER 2
STUDY AND ANALYSIS OF UAP THAT APPEARED IN THE SKY AS THE HALCONES PLANES DEPARTED

SECTION 1: INTRODUCTION

This is an analysis and discussion of images of dark dot images of objects or “UAP” that appeared in the sky in the H1 and H2 videos as the Halcones airplanes were leaving the area. A dark dot (UAP) image appears in each frame of H1 from 17.4 seconds to 18.2 second elapsed time as measured from the beginning of the video (time zero set at the first frame; this time period can also be identified as frame 175 to frame 183 with the first frame of the video labeled as 1). The locations of the dark dot relative to the background clouds form a nearly straight line and make it appear that a single object crossed part of the field of view of the camera. There is also a series of frames of H2 in which a dark dot appears to move in a straight line relative to the background clouds. These frames run from 12.52 sec to 12.88 sec elapsed time from the beginning of the video (time zero set at the first frame; this time period can also be identified as frame 314 to frame 322) Whether or not the object in H2 is the same as the object in H1 depends upon the timing of the two videos. The elapsed time in H2 can be synchronized with the elapsed time in H1, to at least within one frame of H1 – 0.1 sec - by comparing the locations of the departing planes with cloud features that appear in both videos (the airplanes act as a "clock" that appears in both videos).

SECTION 2: UAP IMAGES IN H1

The frames of interest in H1 are shown below starting with frame 175. The object of interest appears as a dark spot at the (approximate) center of the circle drawn in each frame. It should be noted that conversion to the Microsoft WORD picture format reduces

FIGURE 22: 17.4 sec (Frame 175)

the image resolution somewhat so the image of the object is less distinct in this presentation than in the original. But it should also be noted that the object appears just as a faint dark dot even in the original.

FIGURE 23: 17.5 sec (Frame 176)

FIGURE 24: 17.6 sec (Frame 177)

Frame 178 is shown below as a composite picture following the individual frames.

FIGURE 25: 17.8 sec (Frame 179)

FIGURE 26: 17.9 sec (Frame 180)

FIGURE 27: 18.0 sec (Frame 181)

The following picture shows all the locations of the object plotted onto the frame at 17.7 sec (frame 178). The arrow indicates the location of the dot at 17.7 sec. The locations indicated for 18.1 and 18.2 seconds (frames 182 and 183) are "best guesses" since the dot is so faint as to be difficult to distinguish from photo noise.

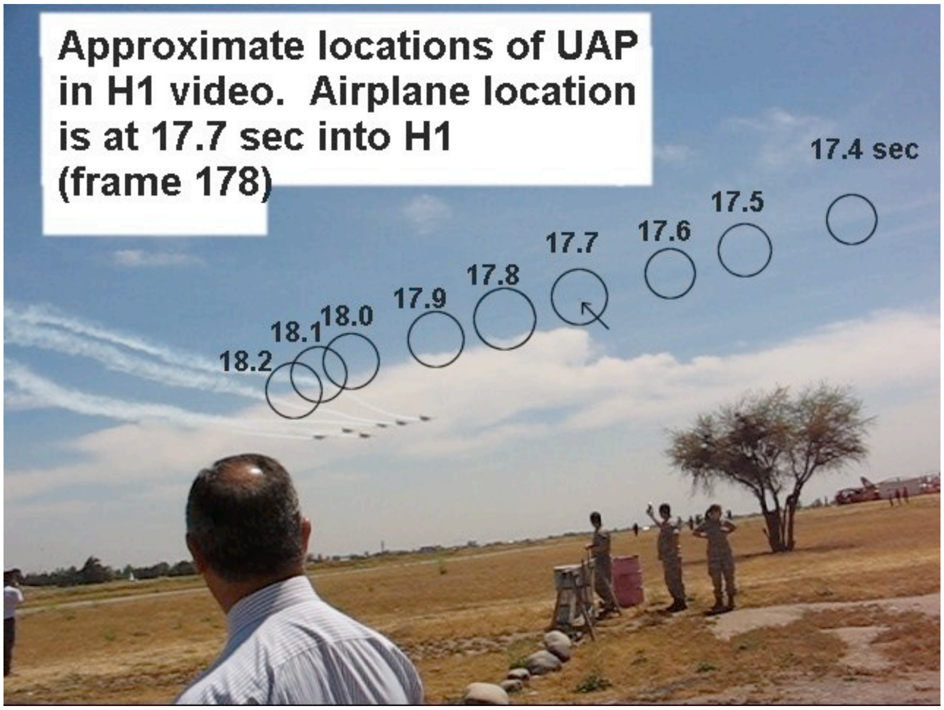

FIGURE 28: LOCATIONS OF DARK DOT UAP IN H1

The images below are blowups of the object/dark dot as it appears in all the frames where it can be seen. Unfortunately, conversion to WORD picture format makes these images even more difficult to see. (If you read this on a computer you can click on the corner of a picture and then drag to stretch it. Then the dark dots become visible.)

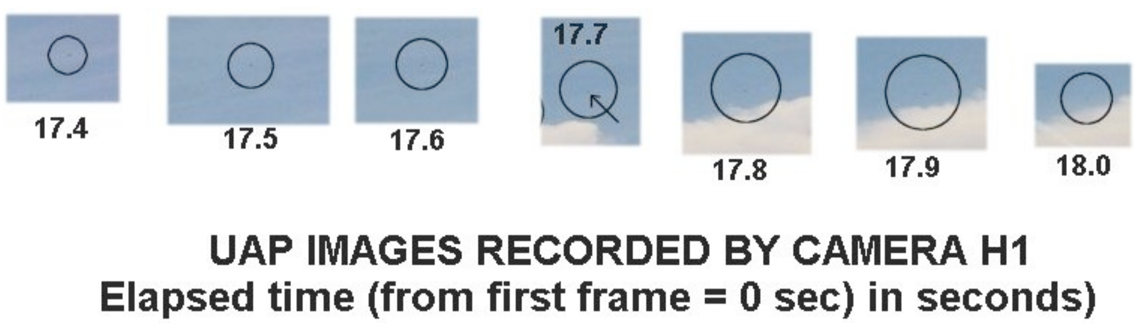

FIGURE 29: DARK DOT UAP IMAGES

SECTION 2: DARK DOT UAP IN THE H2 VIDEO

Dark dot UAP images also appear in the H2 video as the planes depart. The images and their locations are indicated frame-by-frame below, starting with the second frame. The location in the first frame is illustrated in the composite picture that follows the individual frames. The locations are indicated by the vertical line under the dot. Note that the airplane images are larger and the field of view is smaller than in the H1 video.

FIGURE 30: THE SECOND LOCATION

FIGURE 31: THE THIRD LOCATION

FIGURE 32: THE FOURTH LOCATION

FIGURE 33: THE FIFTH LOCATION

FIGURE 34: THE SIXTH LOCATION

FIGURE 35: THE SEVENTH LOCATION

FIGURE 36: THE EIGHTH LOCATION

FIGURE 37: THE NINTH LOCATION

Below is a composite image in which all locations are shown including the first in the frame that shows the airplane location at the time of the first dot image in H2.

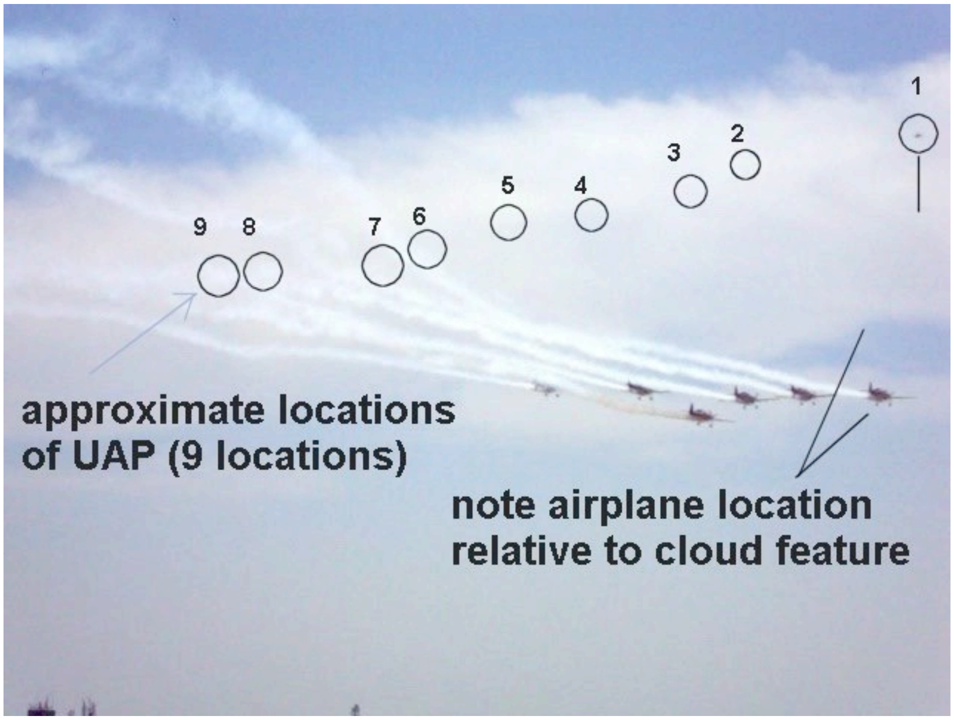

FIGURE 38: UAP LOCATIONS IN H2 SUPERIMPOSED ON THE FRAME THAT FIRST SHOWS THE DOT (FRAME 314)

The locations of the dark dot in this portion of the H2 video form a nearly straight line as do the locations of the dot in the H1 video as shown above. The slopes of the approximate straight lines through the dots in the two composite pictures are virtually identical. Therefore the question arises, could it be that the H2 camera recorded the same object that made the images in H1?

To answer this question one first notices that the first appearance of the dark dot in the H2 video comes *after* the last appearance in H1. To see that this is true compare the airplane locations relative to cloud features (shapes): the locations of the airplanes act as a clock. As shown in the comparison illustration below, when the dot object UAP first appears in H2 (frame 314) the airplane at the right side of the formation is below the widest area if a blue "hole" in the white cloud (see the black vertical line at the right side of the frame that first shows the object in H2). Frame 180 (17.9 sec) from H1, at the right side of the illustration below, shows that at the time of frame180 the airplane had not yet reached the hole in the cloud. In fact, it would take about 11 frames or 1.1 second to reach the location shown in H2, frame 314. Since the airplanes were flying continuously at a constant speed the comparison just described means that the *first* appearance of the object in H2 occurred 1.1 sec after the object was recorded in frame 180. One can barely detect a dark object in frames 181, 182 and 183 (180, 181 and 182 sec) as indicated.

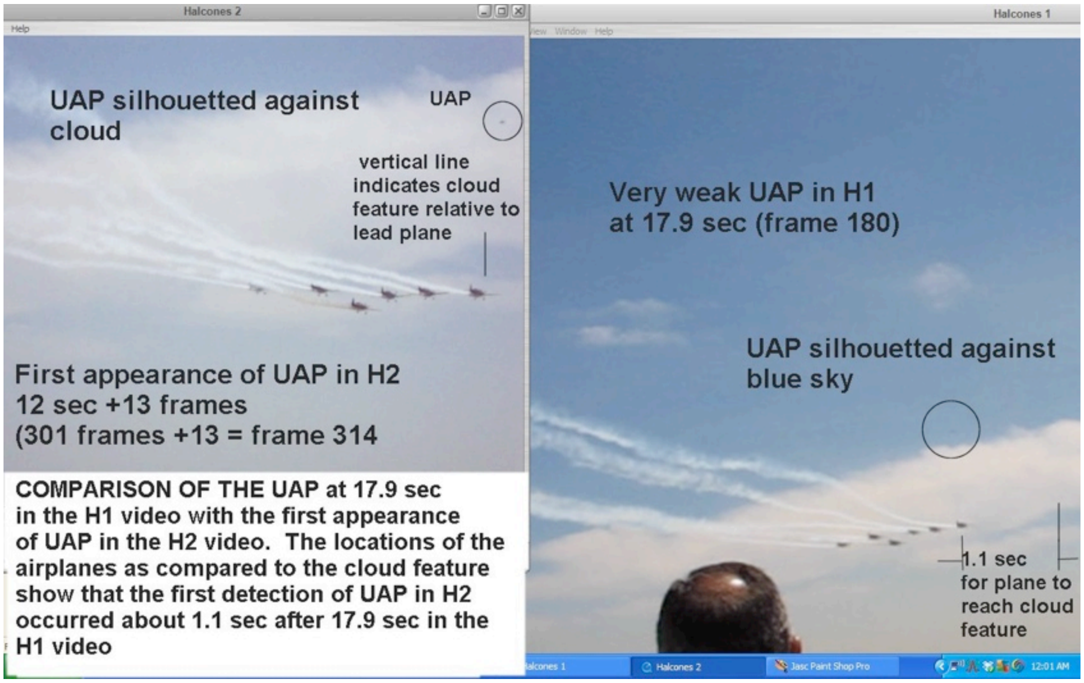

FIGURE 39: TIME DIFFERENCE BETWEEN H1 AND H2

above. Since these frames are 0.1 sec apart, 183 occurred 0.3 sec after 180. That means that the *last image of a dark object in H1* occurred 1.1 – 0.3 = 0.8 sec *before* a dark object appeared in H2. There is a gap of at least 0.8 sec between the *loss* of a UAP in H1 and the *acquisition* of a UAP in H2. This suggests, but does not prove, that the UAP in H2 was not the same as the UAP in H1.

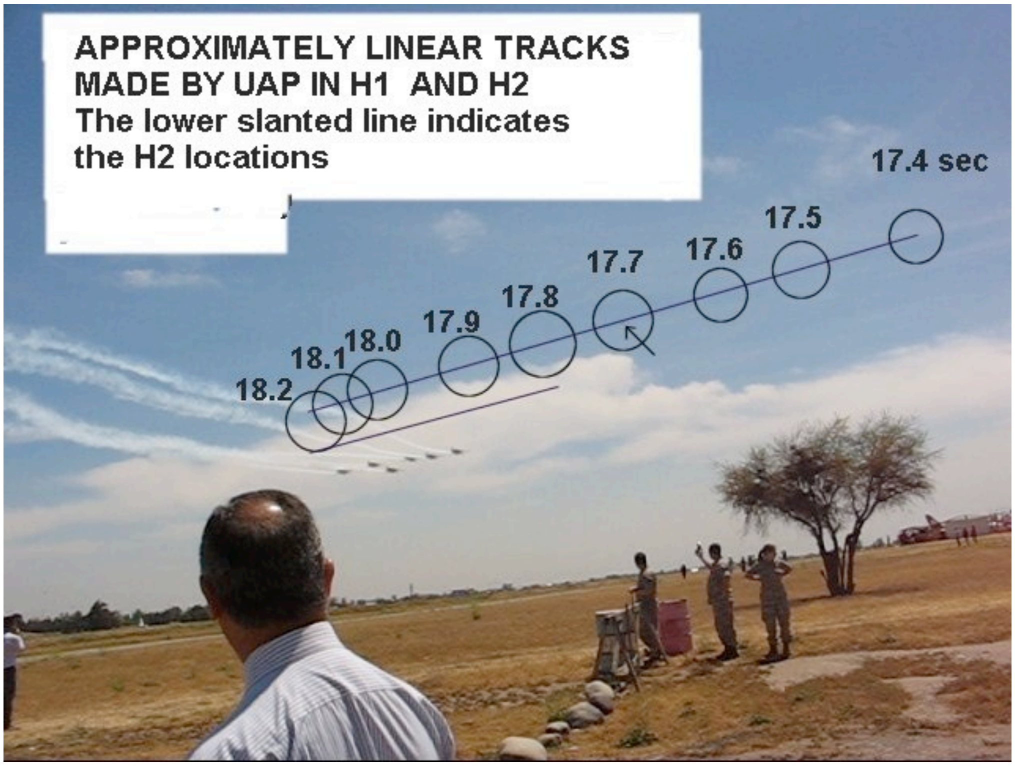

FIGURE 40: COMPARISON OF TRACKS OF UAP IN H1 AND H2

There is another reason to doubt that the same UAP appears in both videos. Inspection of the individual frames of both videos will show that UAP in H1 continually appears silhouetted against the blue sky above the cloud, whereas the UAP in H2 appears silhouetted against the cloud, as illustrated by the lower slanted line in Figure 40. That means that the angle of elevation of the UAP in H1 is greater than the angle of elevation of the UAP in H2. Yet another reason to question the identity of the UAP in the two videos is that the right end of the H2 location line is at a considerable distance from the left end of the H1 location line. This means that, to have one object make both tracks would require that, after traveling continually downward and to the left to the location at the left the end of the H1 line, the object would have had to reverse direction and, without being "seen" by the H1 camera, travel to the right and upward to get to the beginning of the H2 line. It would have had about 0.8 sec or 8 frames of H1 to make this change in path without being seen. Then, as the object traveled along the lower (H2) track it should have been visible in the H1 video.

For these reasons, but mostly because of the time difference and track difference I conclude that the two videos show different objects. Hence there is no triangulation possible and so they could be very distant and large or small and close by.

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CONCLUSION

It was reported that several videos taken during the Nov. 5, 2010 El Bosque airshow contained images of “anomalous phenomena” or “UAP”, specifically images of an object (or objects) that appeared to fly through the sky at high speed as the airplanes flew by. Initial analyses suggested that these objects were insects but then the shape and brightness structure of the largest images were studied and it appeared that insects would not make such images. Instead it appeared that the largest images resembled the classic “flying saucer,” which would mean the objects were large and distant and traveling very fast. Unfortunately there was no direct evidence in any video that proved an object was distant and large. Therefore a search of various portions of two videos was carried out to determine whether or not a triangulation could be accomplished using anomalous images that appear at the same time in the two. Anomalous images (dark dots) were found in four portions of two videos that show the Halcones flying team approaching and flying past the camera positions which were 20-30 ft apart. A careful study was made of the anomalous images in the Halcones 1 video under the assumption that it could be used along with the Halcones 2 video to accomplish a triangulation. Analysis of the first section of the H1 video provided a range of possible distance-size - speed relationships ranging from insect size and speed to “saucer” size and (great) speed. Unfortunately, a similar study of the H2 video showed that the anomalous images in that video did not occur at the same time as the anomalous images in the H1 video. Thus a triangulation was not possible. The failure of the images in the H2 video to appear in the H1 video, and vice versa, could be because the object was small and close to the H2 camera and thus within the FOV of H2 but not within the FOV of the H1 camera that was 20-30 feet from the H2 camera. Hence, lacking proof (by triangulation) that the object was distant (and therefore large) and lacking conclusive proof that a flying insect could not make an image such as recorded on the video, one may conclude that the “anomalous phenomena” images were, in fact, images of insects. (This conclusion can, of course, be changed or reversed if proof of large distance becomes available.)
(Analysis performed March – July, 2012)