REANALYSIS OF THE MARCH 13, 1997 VIDEO BY DR. LYNN KITEI

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INTRODUCTION

This analysis is directed toward answering the question: could the lights videotaped by Dr. Lynne Kitei, March 13, 1997, have been farther away than the Estrella mountain ridgeline south of Phoenix, or could they have been closer than the mountains? The answer to this question can be rephrased to, what was the direction of the sighting line to the lights (azimuth and elevation)? Once the direction to the lights is known it is possible to determine what else, such as a mountain or sky, was also in that direction. One would hope that the answers to these questions would be definitive, that is that the sighting line to the lights was at a considerable distance (several degrees) above or below the ridgeline, as viewed from Dr. Kitei's residence. If the analysis shows that the angular elevation of the lights was greater than the angular elevation of the ridgeline then the lights could have been either closer or farther than the mountains. On the other hand, if the elevation of the lights was definitely lower than the elevation of the ridgeline, then the lights had to be closer than the mountains.

In either case, above or below the ridgeline, it is not possible from her video alone to determine the actual distance. If the lights were closer than the mountains, then they might have been associated with lights reported by the air traffic controllers who reported seeing lights generally west of the airport.

CALIBRATION OF THE VIDEO IMAGES

In order to determine the direction to the lights from Dr. Kitei's house it is necessary to determine the azimuth (horizontal direction) and elevation (angular height) of the lights. In order to do this it is necessary to calibrate the video images to determine the sighting directions to the lights as compared to the sighting directions of some geographic features, specifically ground lights. These should be lights that appear in the video and in a reference evening photograph of the same scene which shows both ground lights and the background mountains. Direct calibration could be done by using a transit to measure the angle between a pair of lights which can be seen in the video. However, no transit has been available for this nighttime use, so the video images have been angle calibrated by comparing the spacings between distinctive lights in the video with the spacings between the same lights as seen in reference evening photograph when the distant mountains are also visible.

Figure 1 shows the reference evening scene that shows many city lights, both nearby and far from the camera, and the background mountain ridgelines. It also shows the calibration of the picture in terms of angle per pixel. This calibration is based on the measurement of the effective focal length (EFL) of the camera. The EFL was determined using test photos of a 3' ruler at 30' distance and taking into account the extra magnification when the 35 mm format negative was converted to a 4" by 6" (cropped) print which was subsequently digitized. The EFL was found to be 335.6 mm. This means that a 1 mm distance on the print is an angle equal to (1/335.6) = 0.00298 radians/mm (about 3 mr/mm; mr is the abbreviation of "milliradians") which corresponds to 0.171 degrees/mm (17.4 mr/degree) The width of the photo in Figure 1 is 149 mm which corresponds to 1173 pix (abbreviation of "pixel" of "picture element", the smallest element of a digitized picture), so there are 7.87 pix/mm or 0.127 mm/pix. As shown on Figure 1, the calibration for angle as a function of pixel distance on the picture is (0.171 deg/mm) X (0.127 mm/pix) = 0.0217 deg/pix.

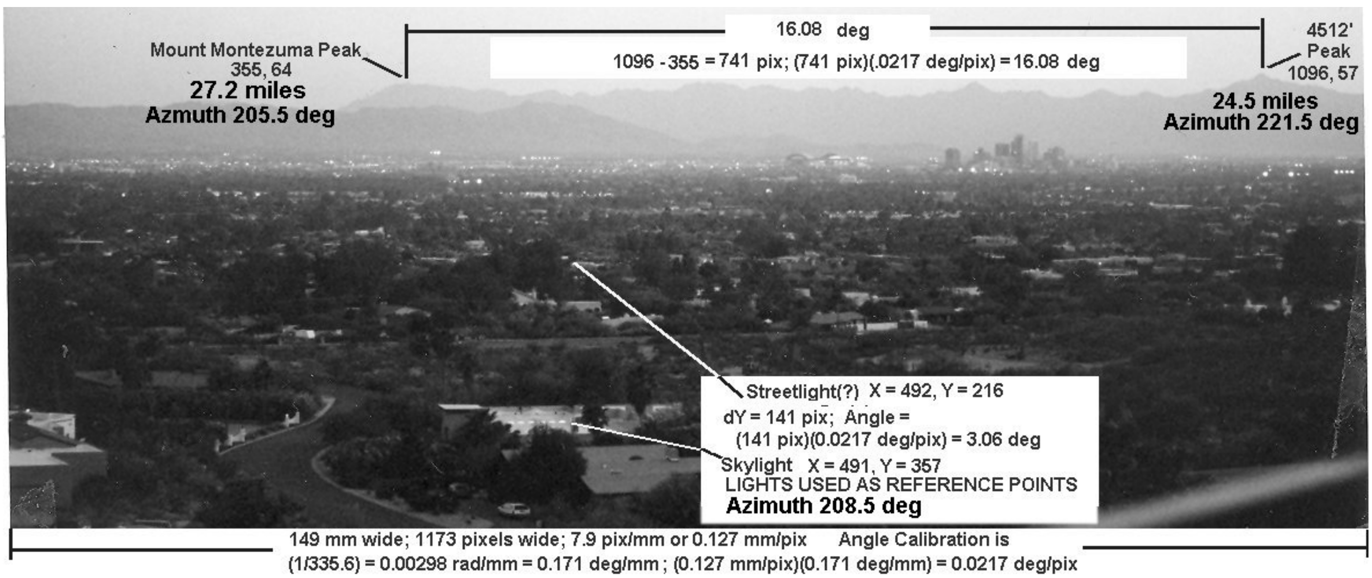

Figure 1 Evening Scene from Dr. Kitei's House and Angle Calibrations

This calibration has been checked against the angular spacing between geographical features that have known locations, namely the mountain peak called Mount Montezuma (4337' high) and the Estrella peak listed as 4512' high on a geographical contour map of the area around Phoenix (DeLorme Mapping). From the location of Dr. Kitei's house the distance to the Montezuma peak is about 27.2 miles and to the 4512' peak is about 24.5 miles. The distance from one peak to the other is about 7.8 miles. Using the law of cosines to find the angle opposite the 7.8 mile side of the triangle, angle $a = \arccos[(B^2 + C^2 - A^2)/(2BC)] = 16.3^o$. As shown on Figure 1, using the previous calibration of angle vs distance based on the EFL of the camera and photo (print), the angle between the two mountain peaks is calculated to be 16.08^o. Considering the great difference in methods of determining the angle between the peaks and the difficulty in locating exactly the Montezuma peak in the photo (the mountain top is quite flat) and the probable inaccuracies in measuring distances on the map, this agreement to within 0.2^o is considered to be very good to excellent.

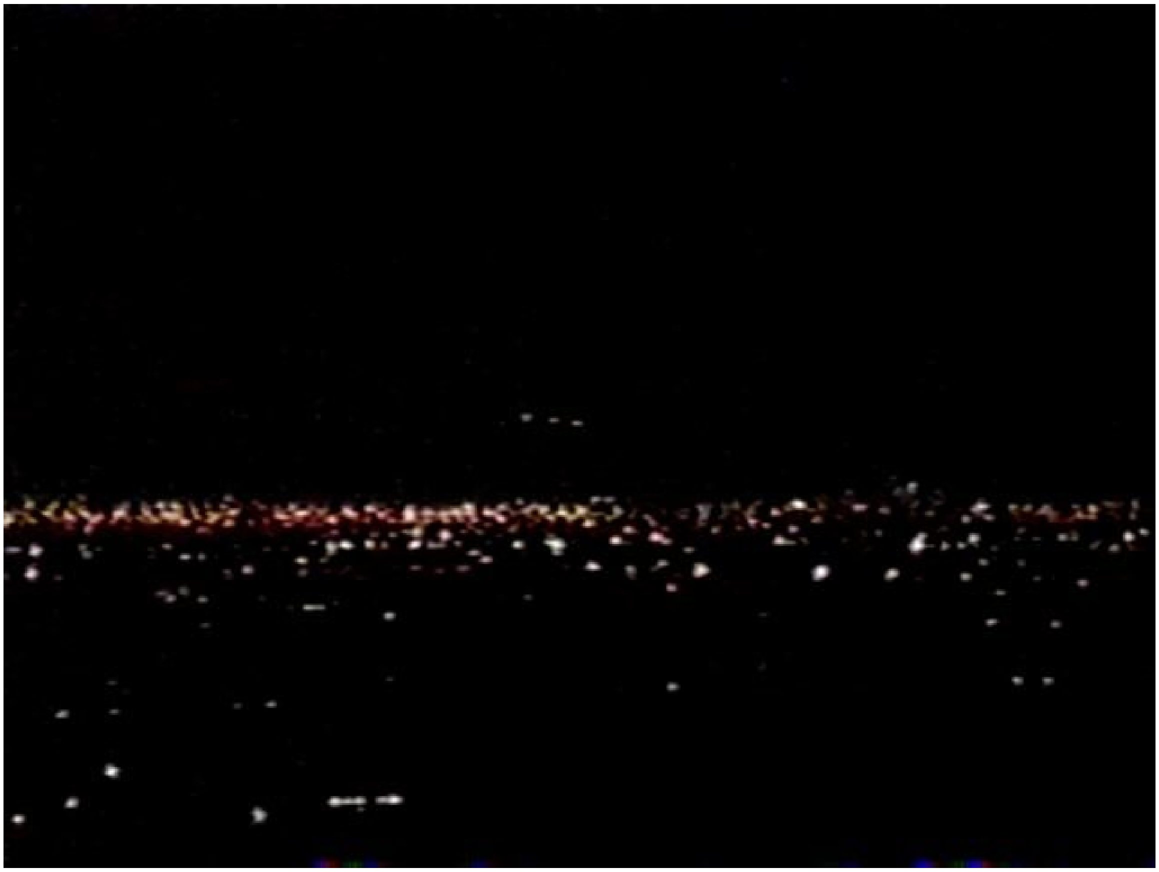

Figure 2 A Frame from Dr. Kitei's Video Showing the Evening Scene, March 13, 1997
Near the bottom left is the line of house skylights and above the
right hand skylight is a solitary light (streetlight?)

TRANSFER OF THE CALIBRATION TO THE VIDEO IMAGES

In order to transfer the angle calibration from the photograph to the video it is necessary to find in the evening photograph at least two lights with a sizable separation that can be definitively identified in the nighttime video. Two lights with a sizeable separation are needed in order to determine the magnification (relative size) of the video frames relative to the evening photograph. One clearly identifiable collection of lights in the video is a line of skylights on the roof of a nearby house (which is at a lower altitude than Dr. Kitei's house). The right hand light of this line of lights is designated, in Figure 1, as a reference light. At a distance in the photo above the right hand skylight there is a solitary light (streetlight?). These two lights, the right hand skylight and the solitary light, have been determined to be clearly identifiable in the video frames. As shown in Figure 1, the angle between these lights is about 3.06 degrees (accurate to a tenth of a degree or so).

Figure 2 shows one frame from Dr. Kitei's video. By comparing Figures 1 and 2 one can verify that there is a solitary light almost exactly above the right hand skylight.

(Note: the evening photograph and the video frame were obtained at different times. Therefore there is no surprise that the lights in the scene are not all identical. For example, one notes that there is a line of 6 skylights in Figure 1 but only 5 in Figure 2. One of the lights was not on at the time of the video.) Figure 3 is another frame presented as a black and white negative image with the lights being black dots. The video image was calibrated by measuring the pixel distance between the images of the skylight and the solitary upper light. From the Figure 1 this distance is known to be 3.06^o. Dividing the number of degrees by the number of pixels gives the video frame calibration in degrees per pixel: $3.06/112 = 0.0273^o$/pix. After this calibration was done, the horizontal and vertical pixel distances between the skylight and light C, the left hand of the three unidentified lights, were measured. Using the calibration these pixel distances were converted to angles. Light C was about 2.4^0 to the right of the skylight which places it at an azimuth of $208.5 + 2.4 = 210.9$ or 211^0. It was also about 6.3 degrees above the skylight. These angles, 2.4^0 and 211^0, were then used to actually locate the position of light C on a portion of Figure 1 that shows the mountains.

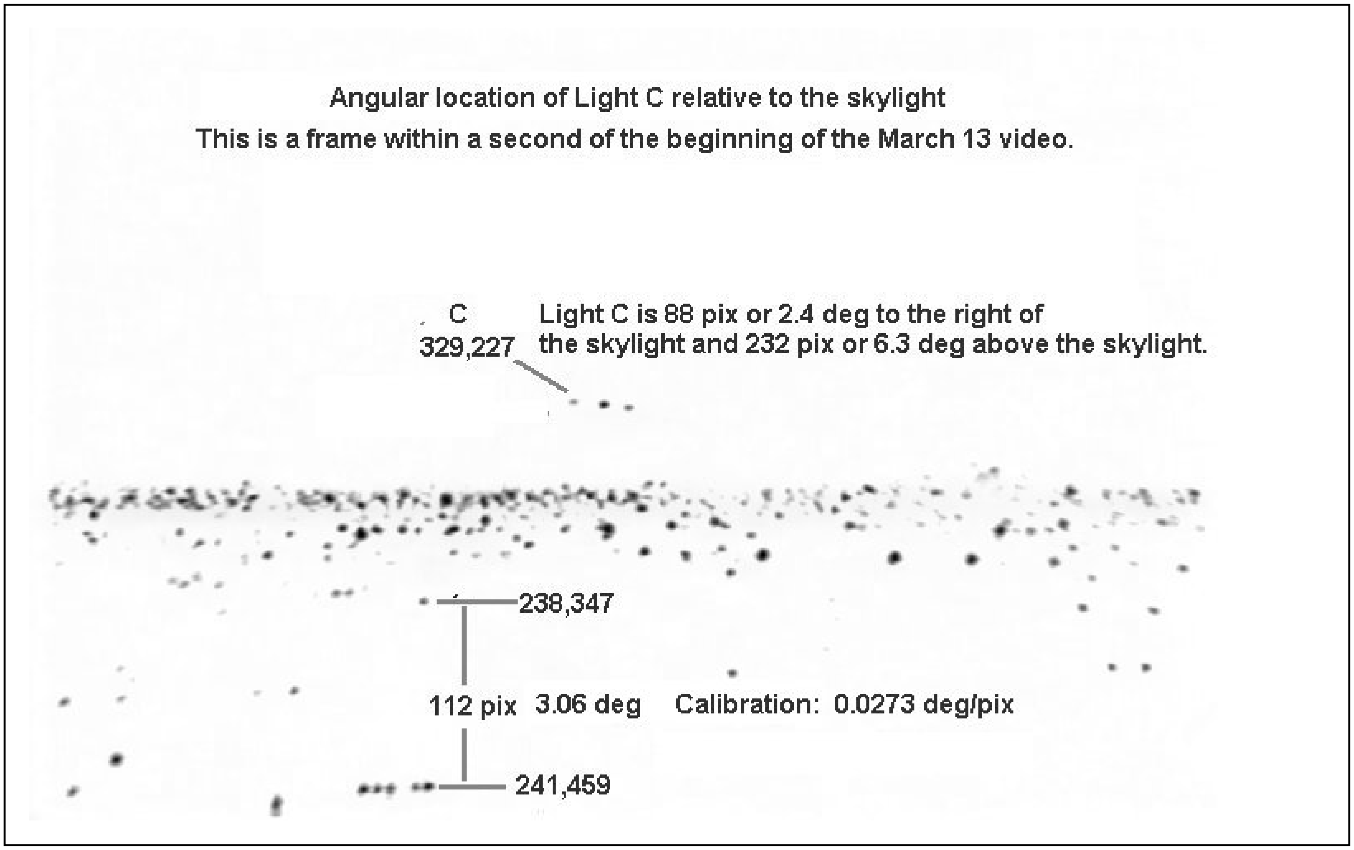

Figure 3 Determining the Angular Location of
Light C Relative to the Skylight

Figure 4 shows the result of using the angles (2.4^0 azimuth, 6.4^0 elevation) relative to the skylight to place Light C onto the evening photograph. It appears that Light C is just at or barely below the ridgeline. Unfortunately the probable inaccuracies in scaling and measurement could move it up or down or left or right a tenth of a degree or more. Thus, at this level of accuracy, one cannot be positive whether the sighting line to light C was above or below the ridgeline.

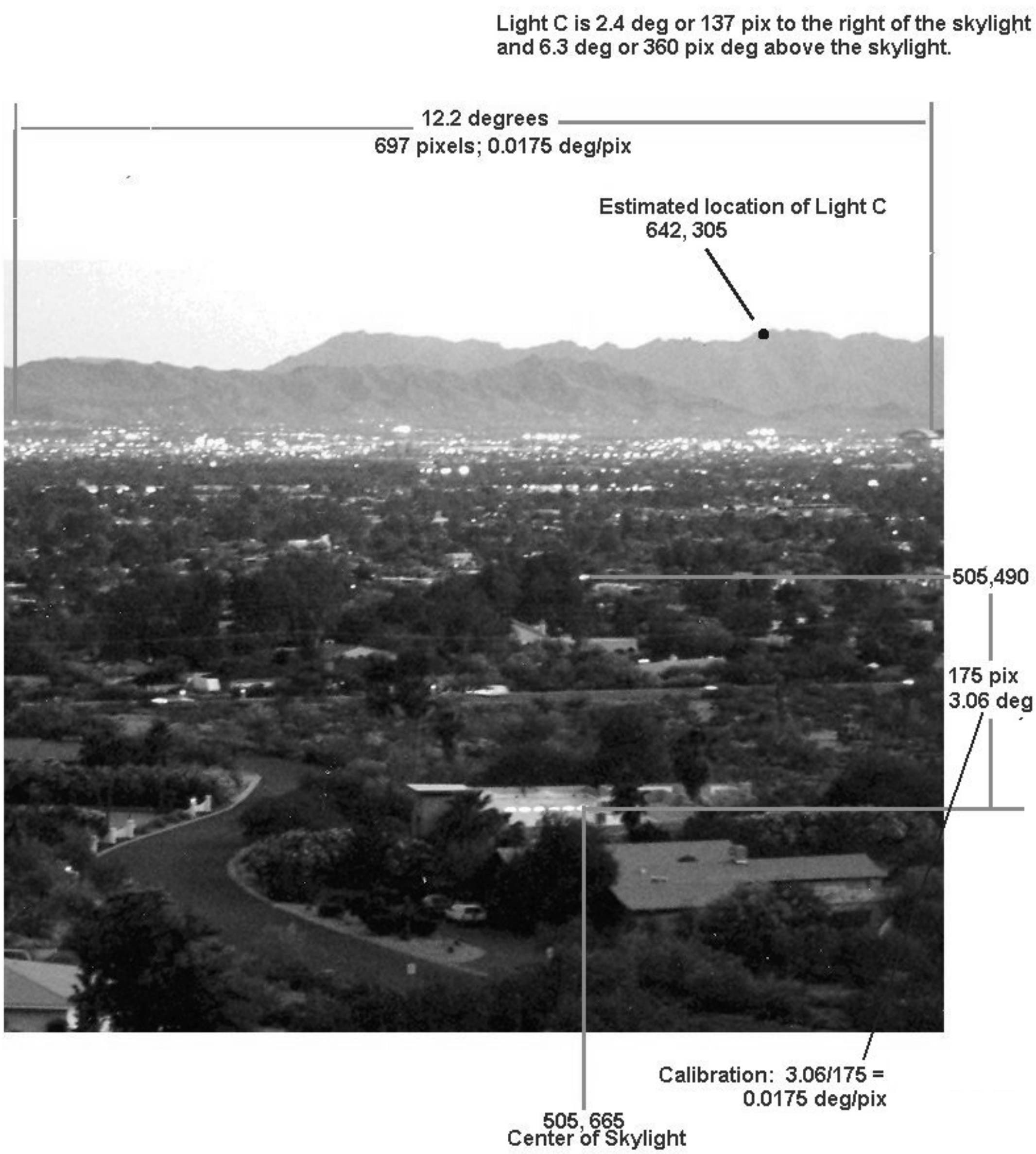

Figure 4 A Portion of the Evening Scene in Figure 1
And the Estimated Location of Light C

IMAGE OVERLAY COMPARISON

Because there are reference lights that definitely appear in both the video and the evening photo, one can overlay the video scene onto the evening reference photo after properly adjusting the magnification of the video frame. The photoprocessing program

(Paint Shop Pro or PSP) allows for photos to be magnified (or demagnified) with great accuracy. Two video frames have been chosen for this overlay analysis. They occur about 11 seconds apart and show both the reference lights (skylight and the upper light) with the maximum available spacing in the video as the camera “zoomed” (magnification level changed). First they were converted to negative grey levels (lights are black dots against a white background, as in Figure 3). Then the magnification of each was changed using the PSP program in a trial and error sequence until the spacing of the reference lights in the video frame image was the same as the spacing of the same lights in the evening photograph. Finally, each video frame was “pasted onto” the evening photograph with the reference lights properly aligned. The whole process is illustrated below.

Figure 5 is a portion of the evening photograph showing the reference lights (circles) and the background mountains.

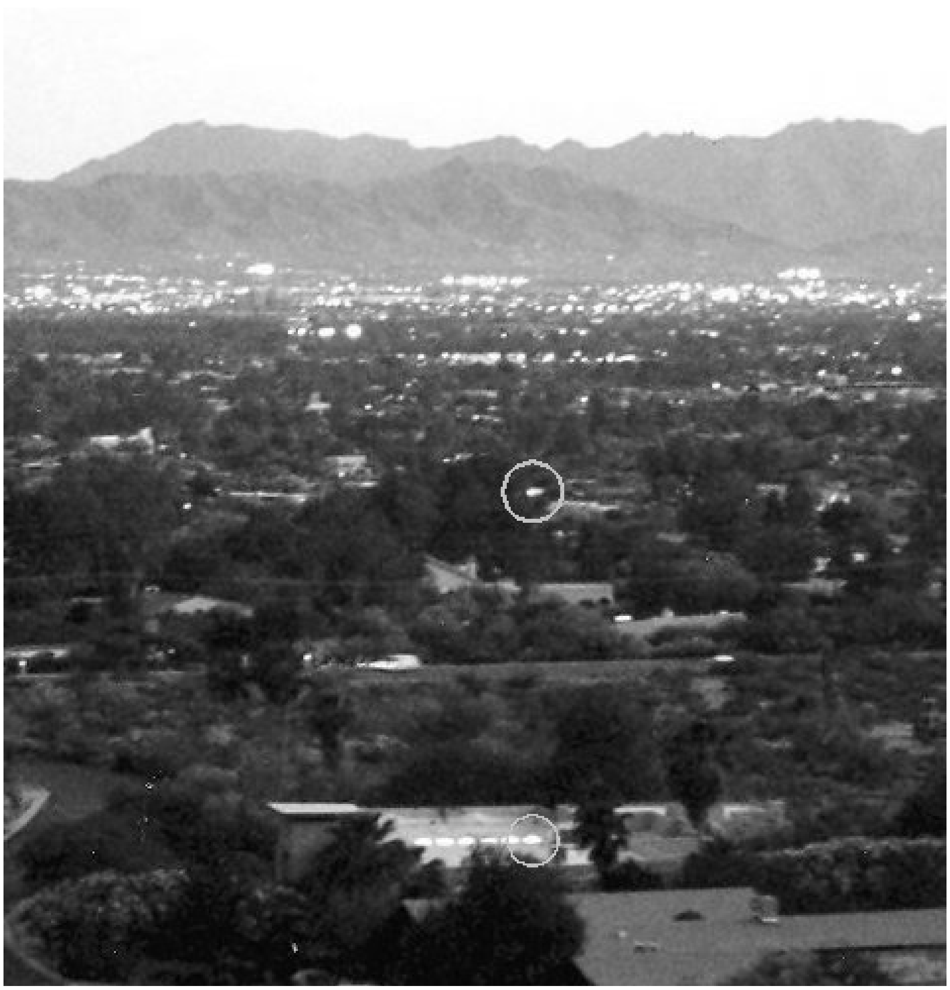

Figure 5   A Portion of the Evening Photograph

Figure 6 is a frame that occurs about 1 second into the video as the scene was “zooming out” (the width of the field of view was increasing as the individual images were shrinking). Note the skylights at the bottom of the picture and the solitary light above. Figure 7 is a frame that occurs about 12 seconds into the video as the camera was "zooming in" and the images were getting larger. By this time the right hand light of the triple had gone out.

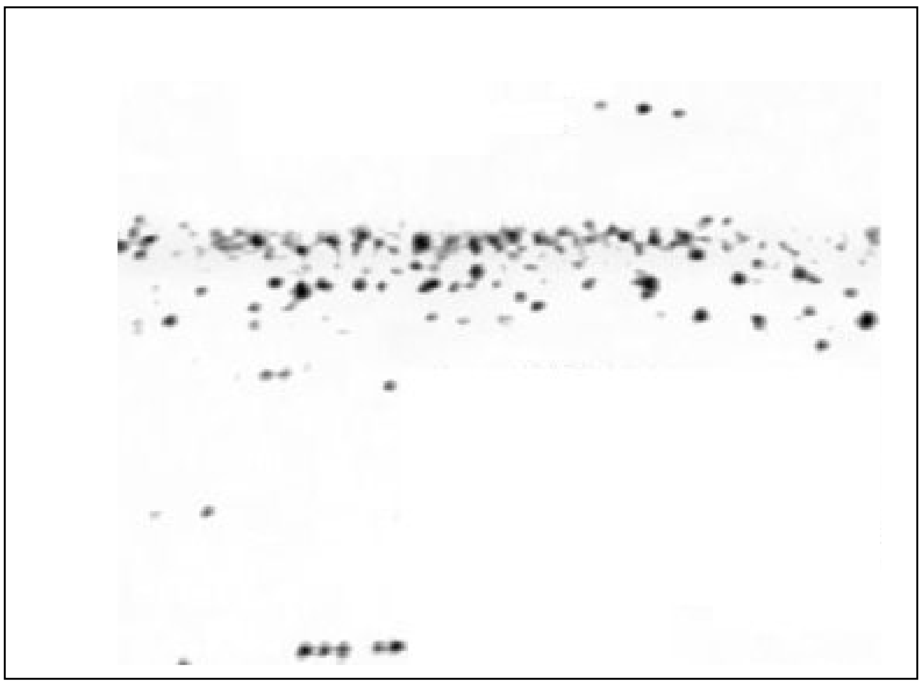

Figure 6 Negative Image about 1 Second Into the Video

Figure 7 Negative Image about 12 Seconds into the Video
Note that the right hand light has disappeared.

Figure 8 shows the evening scene with Figure 6 superimposed and Figure 9 shows the same scene with Figure 7 superimposed.   Note that the black dots representing the reference lights (circled) overlap the images of the same lights in the evening scene photograph, Figure 6. The fact that this overlap is quite accurate provides a measure of confidence that the correct magnification and position registration (up-down, left-right) have been achieved. The unidentified lights are at the upper right corner of each picture. All three lights appear to be the edge of the mountain ridge.

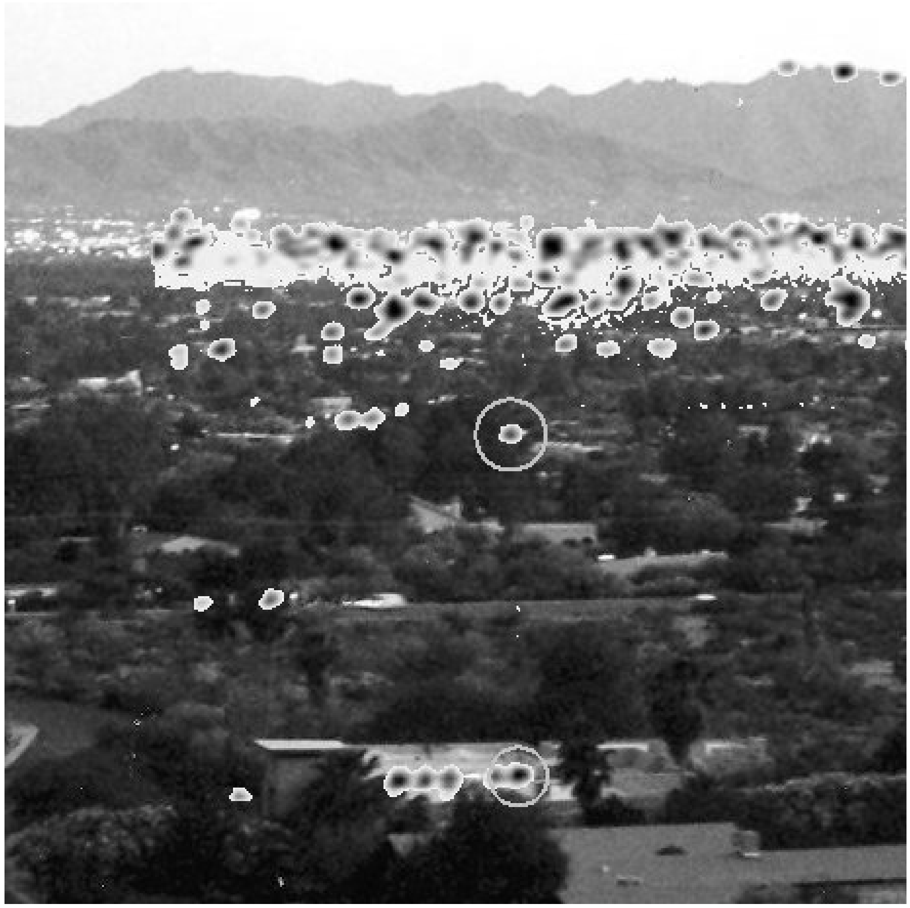

Figure 8 Video Frame at 1 Second Pasted Onto the Evening Scene

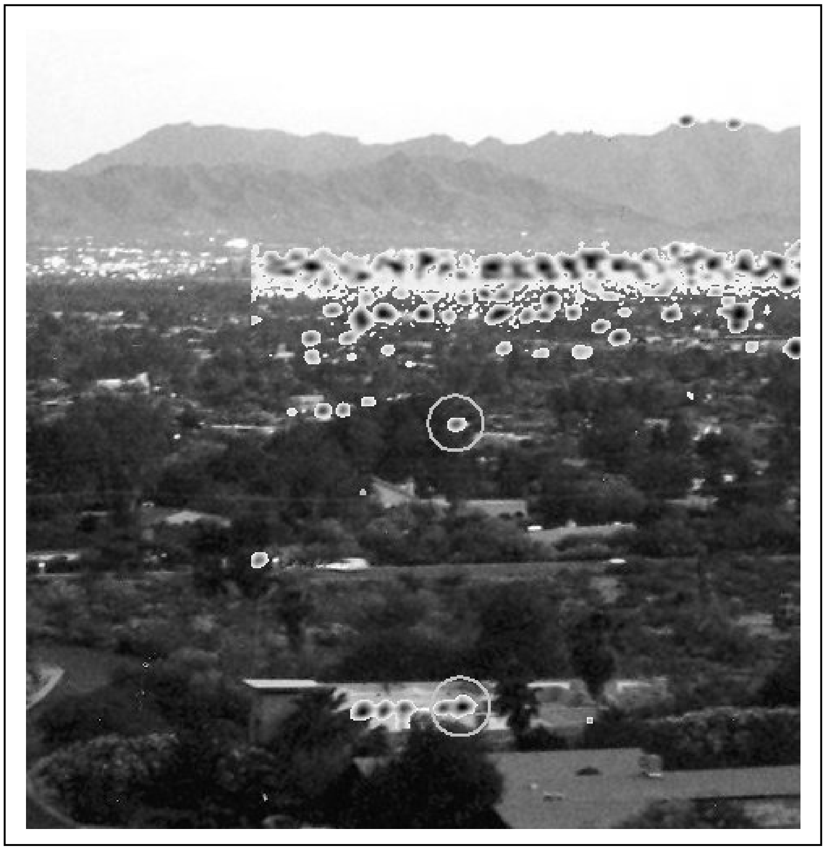

Figure 9 Video Frame at 12 Seconds Pasted Onto the Evening Scene

The direct comparisons in Figures 8 and 9 confirm the more tedious calculation of the location of light C done originally. Unfortunately, these comparisons also are not as definitive as one would like.

DYNAMICS OF THE LIGHTS

The lights have been labeled A, B and C in their order of disappearance. Light A, at the right side of the triple, disappears first in the video, about 13 seconds after the start. Then B about 32 seconds after the start and finally, C after about 58 seconds. The times are not precise because each light flickers for a second or so as it goes out. But, more importantly, two of the lights lasted long enough for a measurement of their motion.

Figure 10 again shows the city lights but the camera has "zoomed in" to the point that the reference lights used previously are not visible in the video. Thus some new reference lights are needed. Figure 10 shows a new reference light and also two sets of lights with different spacings that are needed to determine the relative magnifications of the frames in Figures 11 and 12.   Unfortunately they are not definitively identifiable in the evening photograph so there is no overlay as shown above. The references for magnification are all relative to the zoomed in video scene.

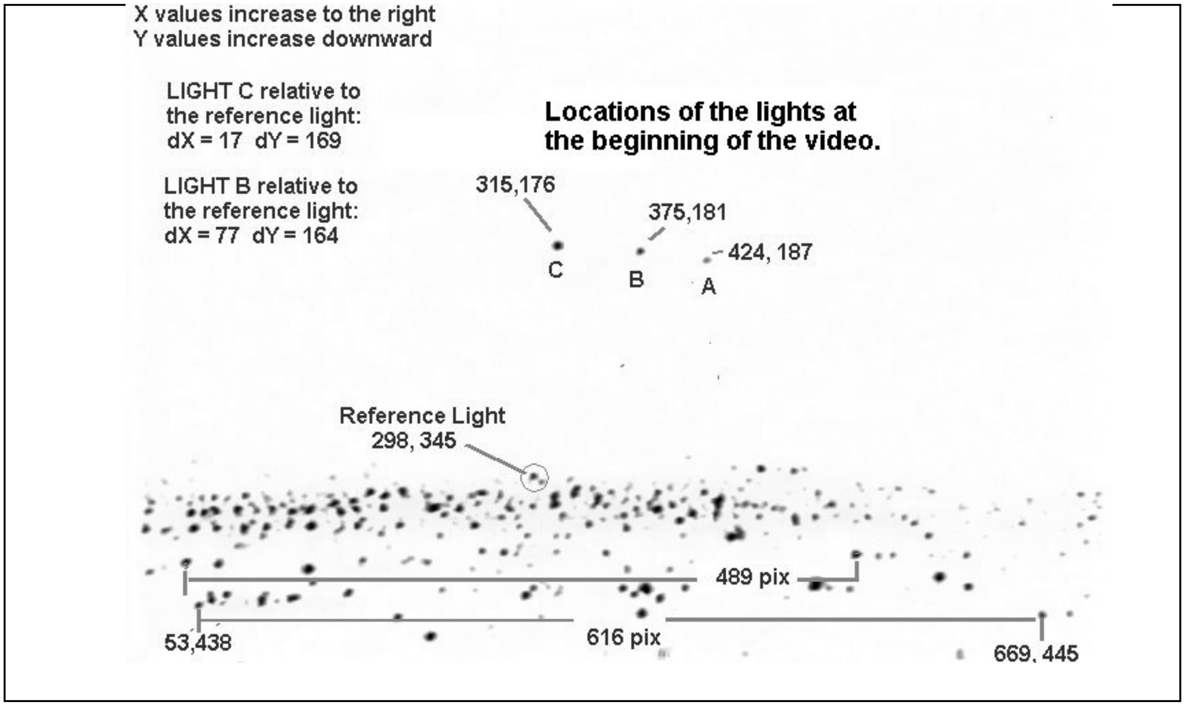

Figure 10 Frame A: Initial Zoomed-in Video Frame Showing the Reference Light
Note the two different pixel distances for magnification calibration.

Figure 11 shows that the lights B and C moved downward and to the left during the first 19 seconds of the video. Then, about 13 seconds later, light B disappeared.

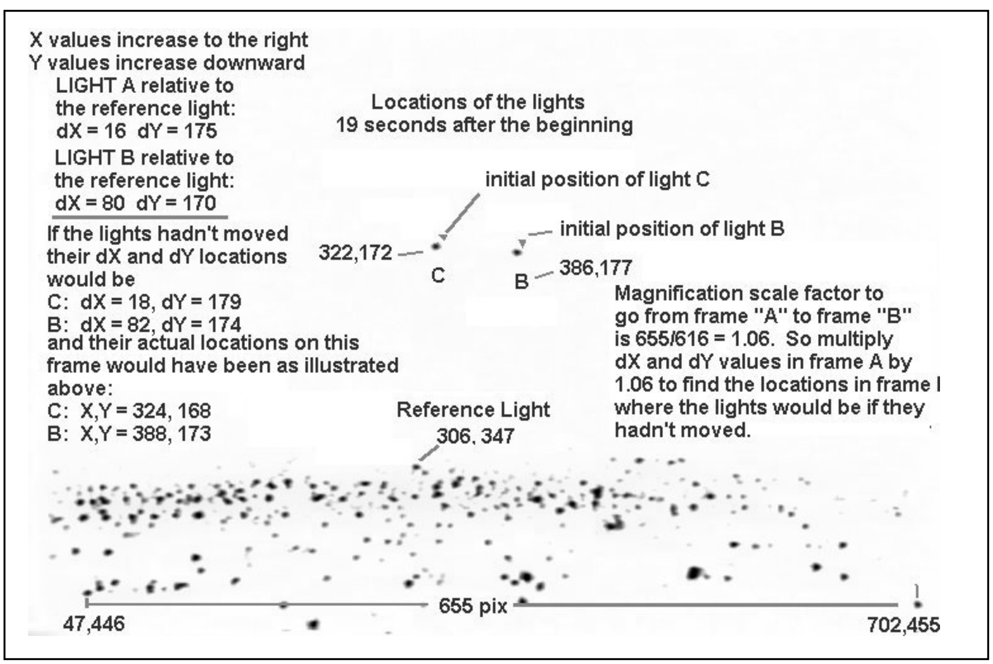

Figure 11 Frame B: Motion of the Lights
The Initial Locations are Compared with the Locations
of Lights B and C about 19 seconds into the Video

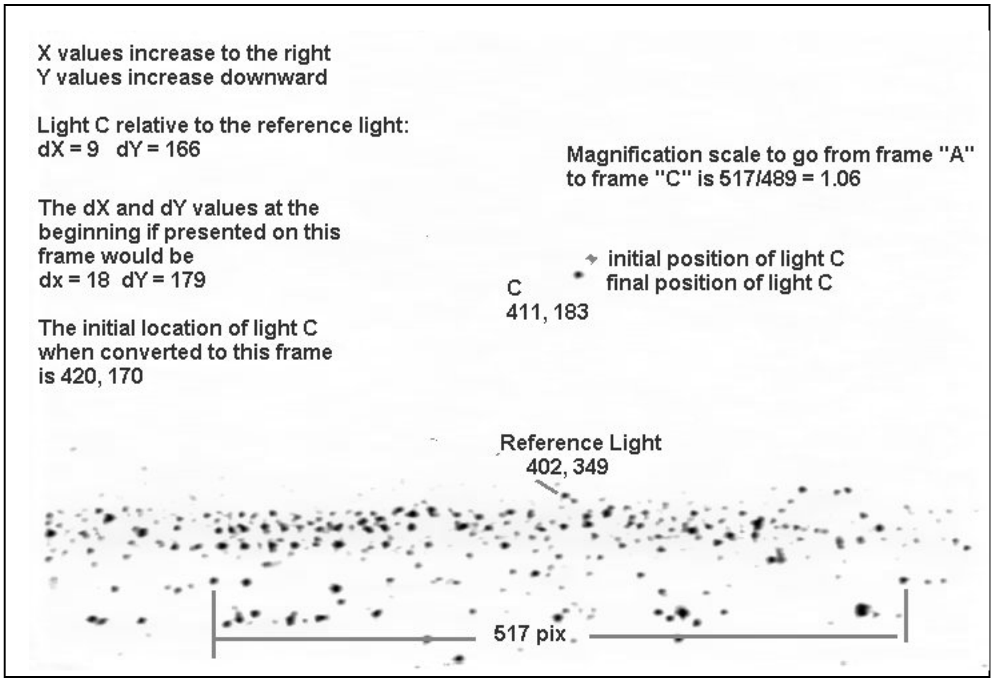

Figure 12 Frame C: Motion of Light C
The initial position of Light C is compared with its
final position about 59 seconds after the start of the video.

These calculations show that the lights were dropping slowly during the time of the video before they disappeared either by "going out," if they were closer then the mountain ridge, or, if they were beyond the mountain ridge, either by going out or by falling behind the ridge.

DISCUSSION

As pointed out in the first paragraph of this article, it was hoped that this analysis would provide a definitive answer to the question of whether or not the lights videotaped by Dr. Lynne Kitei could have been beyond the mountain ridgeline. Instead, the analysis has provided results that are ambiguous.. The locations of the lights appear to be at or just barely below the ridgeline, a result which, if accurate, means the lights were closer than the ridgeline. However, less than a degree of difference in elevation could be large enough to place the lights above the ridgeline. Perhaps an even better analysis could provide evidence that would unambiguously select one of the possibilities, but that might require better data. Where these better data would come from I do not know. Thus at the present time it must be left to the reader to decide which is the correct answer.