VISUAL OBSERVATION OF SATELLITES

1. **Orbital Period** This could be relevant to UAP studies, as an event (i.e. satellite mistaken for a UAP) could be reported once or more on the same pass or on successive passes. The orbital period (i.e. in this UAP context the time of appearance or reappearance) is shown at Figure 1. Thus if the orbit altitude is changed from 200km to 1500km the orbit time changes from 88 to 116 minutes. Hence, UAP sightings with similar characteristics and at these approximate time intervals could be satellite sightings.[1]

2. **Inclination** This is the angle at which the plane of an orbit cuts the equator. It determines the maximum latitude reached by the satellite and hence its potential to be observed in the UKADR.

3. **Re-entry** The effect of air drag (even with much reduced density) causes LEO satellites especially to re-enter the atmosphere. This occurs even with elliptic orbits, which suffer higher drag at each perigee. The lifetime of the satellite is a function of its mass and drag and is thus directly proportional to its mass/area ratio. Because the upper air density is variable, precise re-entry timing is difficult to predict. A visual example of re-entry (Skylab 1) is shown at Figure 2. It is important to note that the colours produced can be white, whitish-yellow, with touches of orange, red, green and blue, all colours often reported as UAP events. Re-entry velocity can be close to 8km sec^{-1} and the pyrotechnic display ceases when it has descended to ~30km altitude, having commenced its glow at 90km altitude. After 30km the remaining fragments fall at a steeper angle. A single calculation shows that a 60km downward path (at 8km per second) lasts only about 7.5 seconds.

4. **Satellite Brightness** Brightness depends on size, shape, surface finish and 'phase angle' relative to the sun. A spherical satellite (e.g. 40+m in diameter (Echo 2 balloon) or 0.3m dia, at the other extreme, may have all its surface illuminated facing the sun. This occurs if a spherical satellite is in the east with the sun just below the horizon in the West. If the sun is in the west when the satellite is in the West, only a crescent is illuminated. The texture of satellite surface (i.e. its surface finish) varies. A white or shiny surface is brighter than a black satellite. It may be partially illuminated and hence seen as an inclined disc, rather than a sphere.

5. **Comparison of Brightness with Stars** It is possible that some UAP reports (from those with knowledge of astronomy) may rate the UAP in terms of the 'magnitude' scale defined by reference to standard stars/planets and even compare a UAP brightness with that of a familiar star (e.g. Pole Star). The level 'magnitude 1' is the brightest with 'magnitude 6' roughly the faintest. the Pole Star has a magnitude of 2.1 Sirius; (a regular UAP report), Mars and Salyut-type systems have a magnitude of -1 (i.e. 2.5 times brighter than a star of magnitude 0 such as Vega, itself 2 times brighter than a star of magnitude 1. Figure 3 relates magnitude against satellite diameter, velocity and range from observer. Although this is short-range it can be roughly approximated to orbit height when a satellite is viewed approximately overhead.

6. **Cylindrical and Balloon Satellites** Brightness is estimated by converting to the brightness of an equivalent sphere from the side-on area of the cylinder (i.e. length x diameter) and then taking the square root to give the equivalent sphere. (e.g. 8 x 2 = $16m^2$ (cylinder side area) = 4m diaspherical equivalent). Clearly the area would be less when viewed end-on. Cylinder area viewed may fluctuate, if they are tumbling, giving the appearance of flashing lights. Balloon satellites are very sensitive to air drag. They may break up in space, producing several reflecting objects.

CONDITIONS FOR VIEWING SATELLITES

7. This is a key topic for UAP filtering. A satellite can only be seen:

- If illuminated by the sun
- If the observer is well in shadow
- If the satellite is against a dark background.

[1] "Observing Earth Satellites" Desmond King - Hele. MacMillan 1983.

8. Certain conditions apply for viewing to occur, and which set the conditions (or eliminate!) the possibility of a satellite being mistaken for a UAV.

- The sun must be at least 10° below the horizon (giving a shadow height of at least 100Km).

- The satellite must be higher than the shadow.

- Faint satellites can only be seen when the shadow height is >100Km but less than the satellite's height, (which may be as low as 200Km).

9. **Earth's Shadow** Evening observations of low satellites are usually possible only during the hour or two while the shadow is climbing from 100Km to the satellite's height. The sequence is reversed in the morning. Because of earth's shadow, a low satellite can only be normally observed from 2 narrow bands of latitude (one in each hemisphere). Figure 4 illustrates the limitations **during northern summer for a satellite in near-polar orbit with the sun in near orbital plane**. The earth's shadow is shown with a sharp edge, but in practice this is fuzzy. The height of earth's shadow is absolutely fundamental for satellite observation, for example, in the Figure (at point P) the shadow height PS is approximately equal to earth's radius (~6000Km), so the only satellites visible overhead at point P would be more than 6000Km high and probably faint and difficult to see. In UAP evaluation most events which catch the eye and might be reported are likely to be bright.

10. Earth's shadow height varies with time of year. Figure 5 shows the variation at 50°N, local time. For viewers near London, Time = GMT. For every degree of longitude west of Greenwich four minutes must be subtracted. This chart can be used two ways; it shows the height of the evening shadow:

- Working from date (e.g. 2 March) at latitude 50°N sunset is ~17.45hrs, twilight lasts nearly one hour - hence the sky will not be dark enough to view satellites until ~18.40hrs, when the shadow height is100Km. By 19.10hrs the shadow has reached 200Km altitude. After that no satellite lower than 200Km height can be seen overhead, though they could still be observed in the West where the shadow height is still lower. By 21.00 hrs the shadow height exceeds 1000Km and many brighter satellites at these altitudes can be seen.

- Alternatively, if the satellite height is known the chart can be used in reverse. This is a less likely scenario in trying to eliminate mis-reported UAV reports.

11. It is observed that (using the 100 and 400 curves at Figure 5) at 50°N on 1 January, the period available for satellite viewing is only from 17.12-18.18hrs. By April this has lengthened to about 1 hour and from approximately 20 May to 20 July a satellite could be seen at any time of the night. In June any satellite higher than 300Km is always above the earth's shadow at latitudes greater than 50°N. These are all important factors in correlation with potential UAP windows of observation. The observing period is actually slightly more than Figure 5 might suggest (since this is plotted for a satellite overhead). Clearly the satellite might be at some other elevation angle. In the dark eastern sky it is sometimes possible to observe before the end of twilight. For a satellite at 400Km altitude at longitudes up to 10° to the west of the observer it is possible to observe up to 40 minutes longer than the figure indicates.

12. A rule of thumb (for 50°N) is that over the greater part of the year (excluding May, June, July) the possible observation time for a faint satellite (~200Km altitude) is one hour and two hours if its height is doubled. As an example (with reference to Figure 5) the observer sees a satellite at 21.30hrs on 29 August the shadow height on the diagram is 500Km. Hence the satellite will be in shadow and visible unless its height exceeds 500Km.

12. **Repeat Observations** Observation of a satellite on successive evenings is subject to longitude changes at which it crosses the latitude of the observer. A satellite appears to be ~1° (0.986°) further west on successive nights due to the 360.986° rotation in 24 hours because the earth spins through 360° 23hrs 56 minutes and spends

the remaining four minutes 'catching up' on the small angle needed to bring it to the same direction relative to the sun. The same satellite will also have a time-shift in arrival at the observer's latitude, by several minutes. Clearly this varies with orbit type. The daily shift to the West is shown at Figure 6 for near circular orbits. Hence, from the UAP aspect reports could be received, shifted in time and elevation angle on successive days/nights with an observer in the same position - or by an observer in a different position.

13. Figure 7 shows two successive ground tracks of a 90 minute period satellite at an inclination of 65°. This shows that the 22.5° shift in track longitude is such that it is unlikely that the same observer will see two successive transits. The spell of visibility of a particular satellite varies as the orbital plane swings westward. For example, a 500Km altitude satellite will reach a point where the shadow height is less than 500Km. The satellite will be visible in the evening for some weeks, but as it swings further west will be invisible because of the glare of the setting sun. Next, it will pass over in daylight for many weeks, then into morning twilight and after a spell of potential morning visibility will once again enter eclipse before repeating the cycle.

14. **Spells of Visibility** Satellites (in circular orbit) can pass over on either a north or southbound track. It is important to note the concept of 'spells of visibility' because these are likely to generate successive spurious UAP reports. It can be shown that evening visibility lasts for $v/4(1-\times)$ days, where v is the length of one evening's visibility time and the value $\times$ (the daily westward shift) is given from Figure 6. For example, for a satellite at 400km altitude, visibility is ~2 hours per evening/night, the value of $\times$ is zero (polar orbit), the visibility is 30 days. With an inclination of 70°, period 92 minutes, then $\times$ is 2.8 (Figure 6), hence the spell of visibility is reduced to $30/3.8 \approx 8$ days. If satellite height is increased the spell of visibility increases. This rule of thumb becomes inaccurate after ~ 1 month - but is of no concern for UAP elimination purposes. The important fact is that a given satellite is observable (given atmospheric clarity) for a number of successive days and this can result in mistaken reporting as a UAP on one or more of these days.

15. After a spell of visibility a circular orbit satellite becomes visible again (from the same location) after $1440/4\ (1+\times)$ days or $12/(1+\times)$ months. Slightly different rules apply to eccentric orbits.

16. **Angle of Elevation** This is one parameter which often occurs in UAP reports. Figure 8(a) and 8(b) show the angle/range/altitude relationship.

17. **Flash Periods** It is possible to time the satellite flash period. This feature may appear in UAP reports. Flashes (seen with the naked eye) from MOLNIYA satellites have been reported at once per minute (even from 40,000km range). These flashes tend to come from flat panels and have magnitudes which can exceed those of VENUS at its brightest.

18. **Sightline Rates** UAP reports occasionally include times and angles. Some examples are:

(a) Satellite at 200km altitude. The minimun orbital speed is $7900 m.s^{-1}$ (e.g. SKYLAB altitude 235km).

(b) Satellite at moon distance travels at $975 m.s^{-1}$.

(c) An equatorial orbit (circular) at 10,200km passes once every eight hours.

(d) A 100-300 nautical mile high orbit passes, typically, once every 90 minutes.

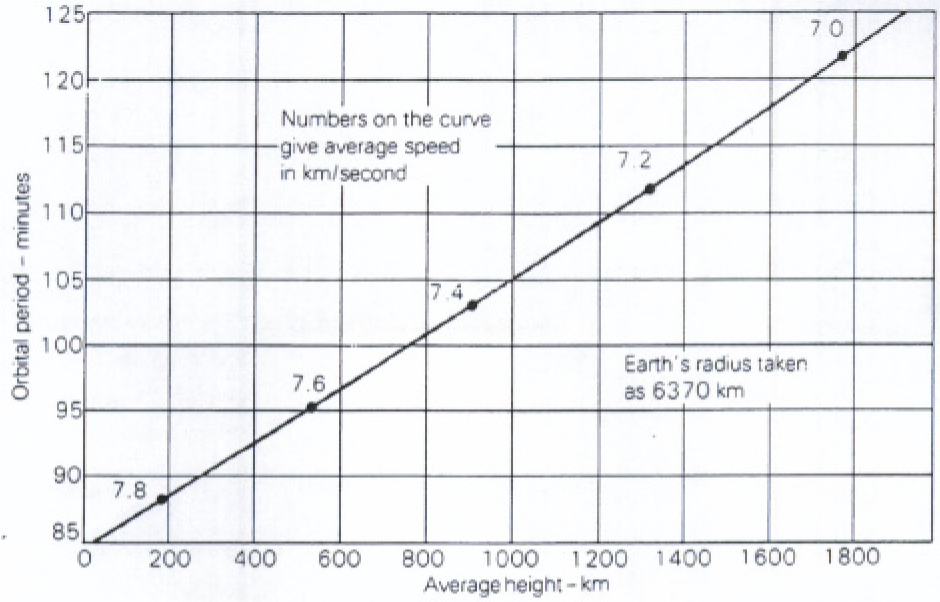

Figure 1: Orbital period of a satellite versus its average height above the Earth (U)

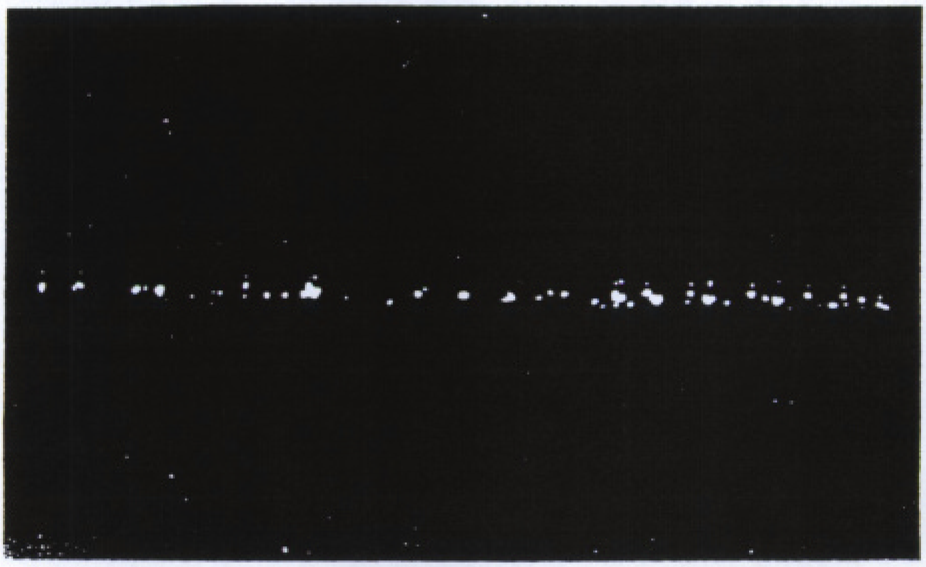

Figure 2: Photograph of the descent of Skylab 1 over Australia on 11 July 1979 (U)

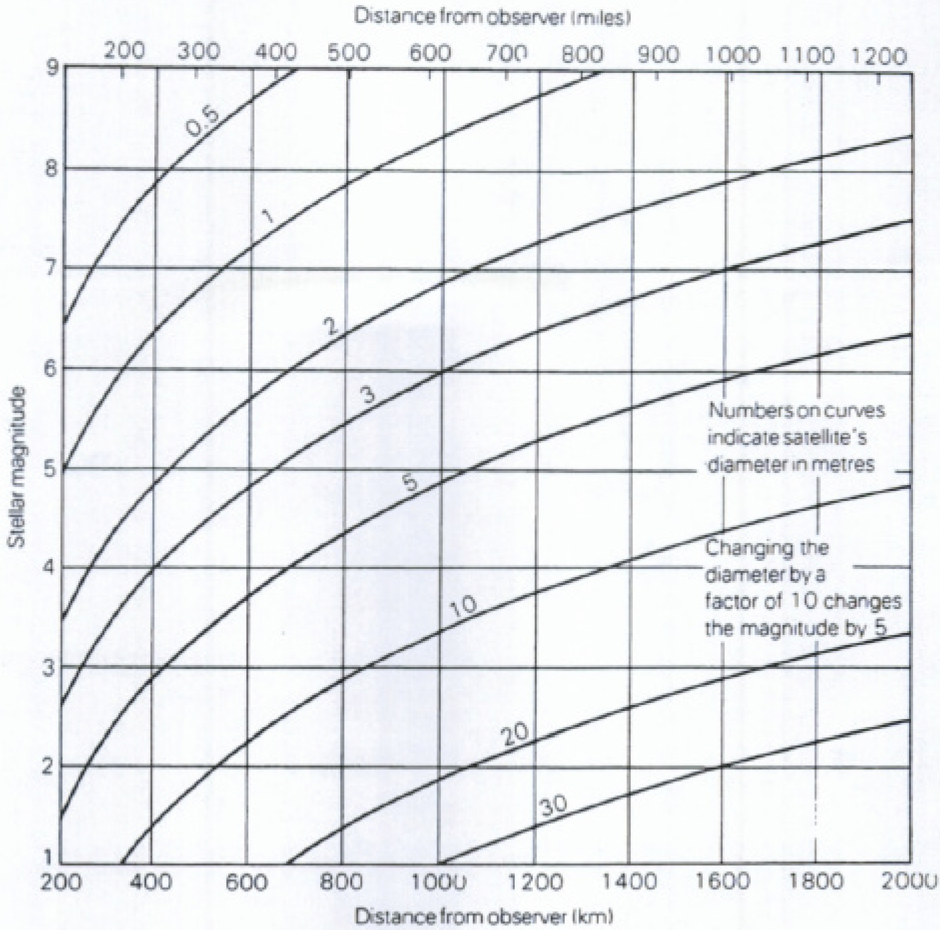

Figure 3: Spherical Satellite - Visual Brightness for given Range and Diameter (U)

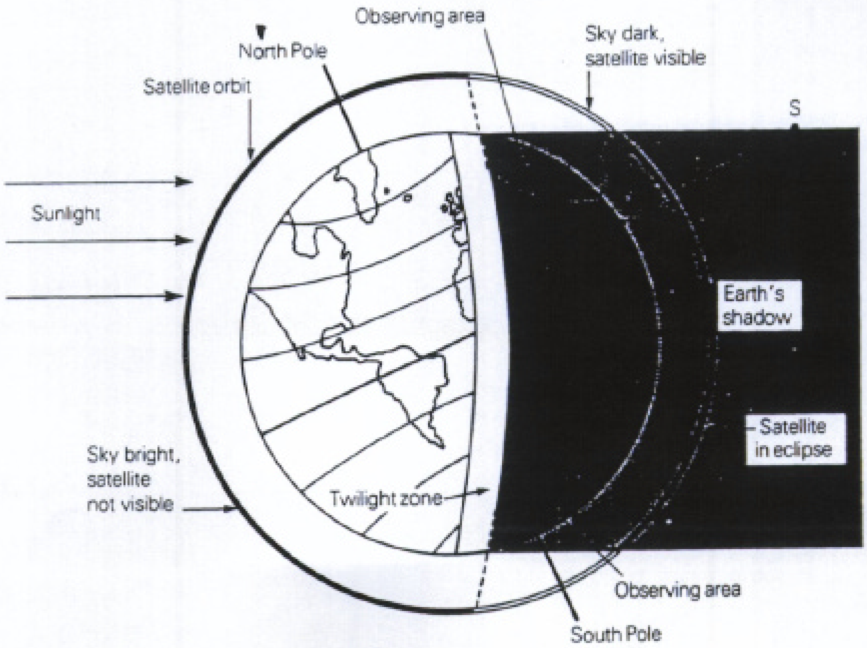

Figure 4: Example - Satellite Visibility Sectors (U)

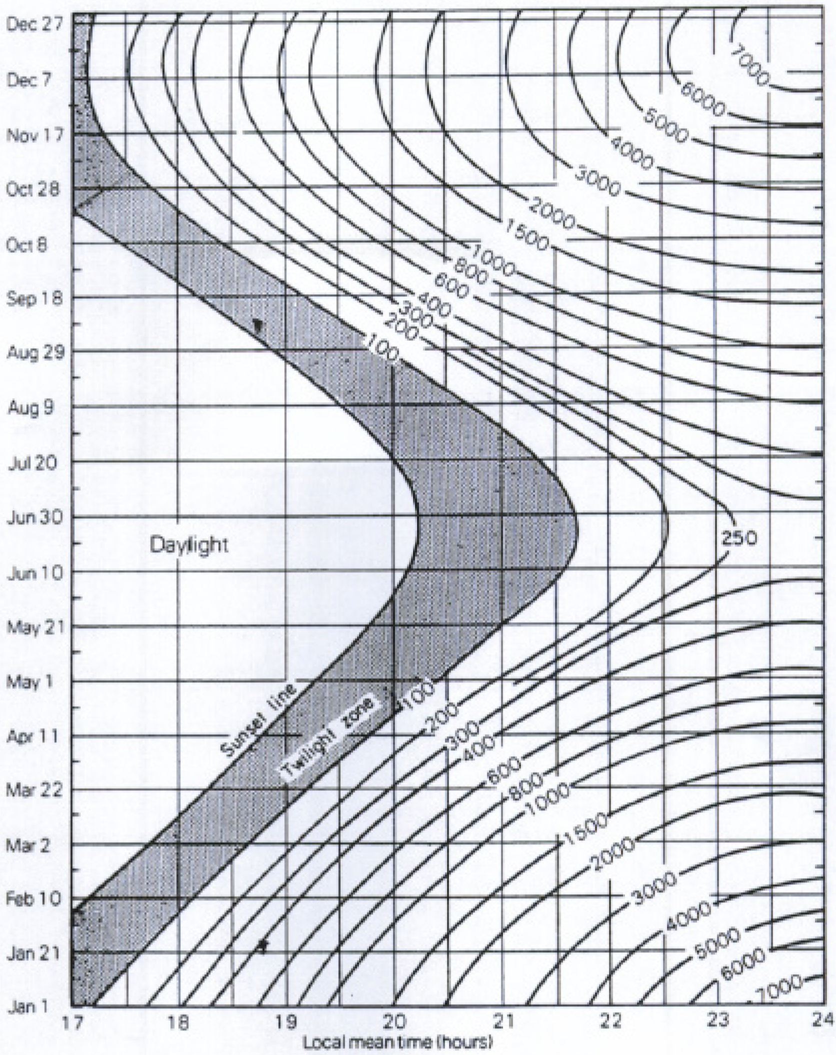

Figure 5: Satellite Viewing Windows (for Latitude 50°N) for Earth's Shadow Altitudes up to 7000Km (U)

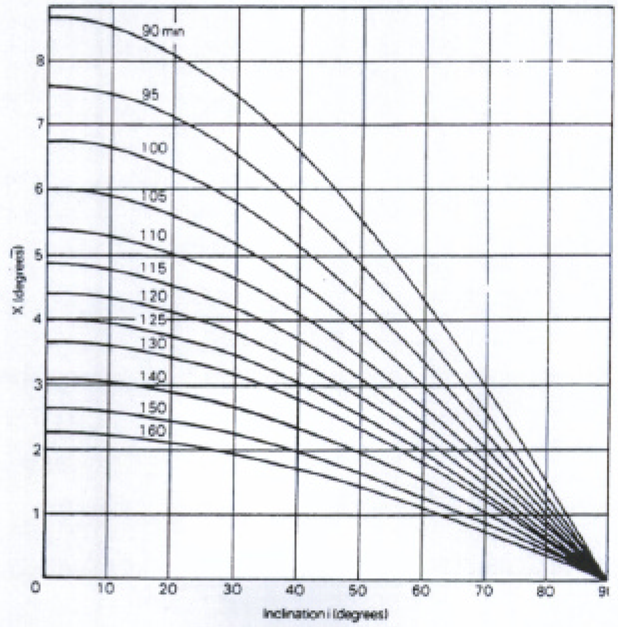

Figure 6: Daily Shift of Observed Position to the West for given Orbital Period (U)

Note: X (Degrees) is Nodal Regression.

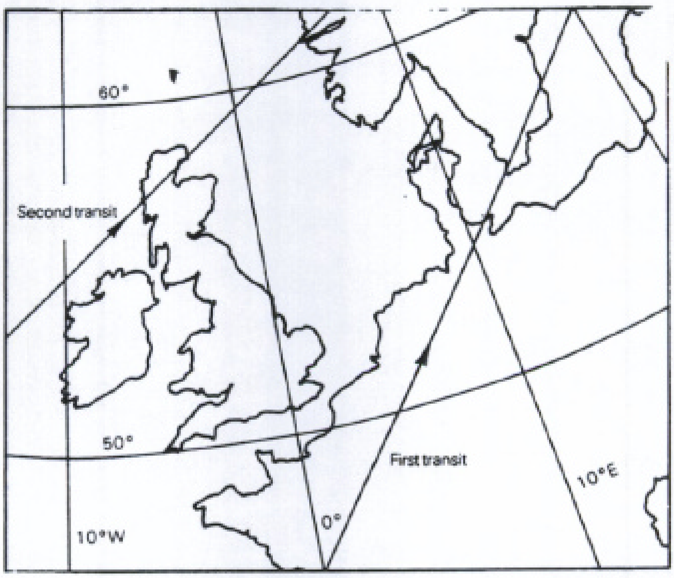

Figure 7: 90 Minute Orbit Tracks at 65° Inclination (U)

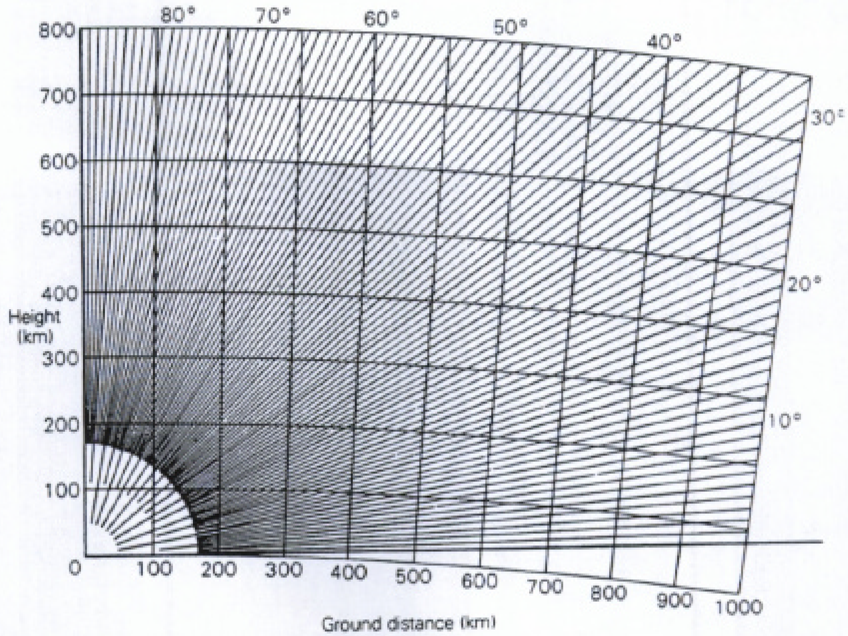

Figure 8(a): Satellite Elevation to 800Km Altitude (U)

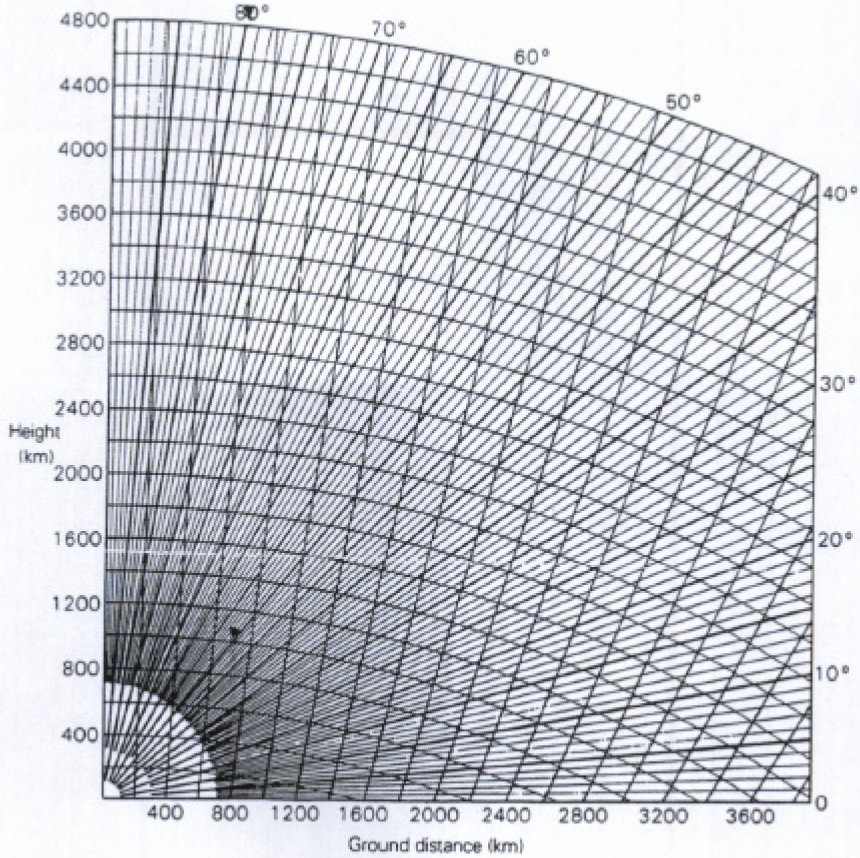

Figure 8(b): Satellite Elevation to 3000Km Altitude (U)

WORKING PAPER NO. 18

PROJECTED SHAPES/SHADOWS, FLUORESCENCE, LUMINESCENCE & SONOLUMINESCENCE

PROJECTED SHAPES AND SHADOWS

1. Frequently UAP reports suggest shadow shapes (i.e. objects apparently seen in silhouette). It is believed that a proportion of these are projected shadows from any object which is opaque, or near opaque at the wavelength of the surrounding light. Thus a shadow with a fairly sharp edge is reported, although much closer examination would show that the shadow is not absolutely sharp.

2. The shadows of aircraft and helicopters are frequently seen on the ground, often in film or video taken from the same platform. Less well known (to terrestrial observers) is the projection of aircraft shapes on to cloud layers and the consequent moving shadows seen from beneath the clouds. Further, it is possible for rainbow-like arrays to be produced through sunshine via aircraft windows, which can be projected on to clouds some kilometres distant. These can be reported as UAPs with colours.

FLUORESCENCE AND LUMINESCENCE

3. Earthlights are seen in the dark but they are not observed by reflected light They actually provide the light energy which the eye receives and be classed as 'fluorescent'', whereas, luminescence is visible light, generated by the conversion of energy invisible to the eye. Luminescence is a general term classified according to the means of excitation; examples are:

- Photo-luminescence is that generated by radiant energy.
- Bioluminescence is generated by bio-chemical reaction.
- Cathodo-luminescence is generated by electron bombardment.

Luminescence is called fluorescence or phosphorescence, depending on the rate of decay; phosphorescence persists for some time. Fluorescence ceases when electron bombardment stops (i.e. within ~10^{-8} sec.). Therefore to obtain continued fluorescence, continuous electron bombardment is needed. (See also para 6 below).

ABSORPTION AND SCATTERING

4. When ambient light impinges on a gas its intensity is affected by the absorption and, as a result its velocity will be less in the medium than in free space. The meduim may not reduce the intensity by equal amounts for all wavelengths. No substance is known which absorbs all wavelengths equally, although some can approach this condition over a wide range of wavelengths. Normally one would expect selective absorption to occur.

5. Bodies can cause different effects for transmitted and reflected light. Hence, an observer on one side of the body, receiving energy which has passed through a gas may observe one colour, whereas an observer of the same object using reflected (i.e. back-scattered) light can see a different colour. True absorption represents the actual disappearance of light, the energy of which is converted to heat motion of the molecules. In the UAP context there appears to be complete absorption when a totally 'black' shape

appears between what are taken to be highly charged 'balls' seen as sources of coloured or white light, usually at the extremities, forming a triangle, cone or rectangle.

6. **Gas Absorption** The absorption spectra of gases at ordinary pressures show narrow dark lines, although it is possible to find regions of continuous absorption. After an atom or molecule has taken up energy from light it may collide with another particle and an average increase in the velocity of particles may occur. Each atom energised can only exist for 10^{-7} to 10^{-8} sec. and unless a collision occurs the energy will be emitted as radiation. At low pressures the time between collisions is long, hence the gas becomes a source of radiation and there is not true absorption. The re-emitted light often has the same wavelength (resonance radiation). Under some circumstances the re-emitted light may have a longer wavelength than the incident light. This is known as fluorescence. In either resonance or fluorescence some of the light will be removed and dark lines would be seen in an examination of the spectral response.

7. **Aerosol Fluorescence** If it is postulated that some UAP comprise clouds of aerosol particles, then it is necessary, briefly, to examine fluorescence from solids. According to Stoke's Law the wavelength of the fluorescent light is always longer than that of the absorbed light. In the UAP context it seems unlikely that (if fluorescence is indeed the mechanism of making an aerosol cloud appear as a visible mass) this could be caused by radiation of the particles by any radar system. The source radiation must be shorter in wavelength than visible light, leading to the postulation that the cause may be IR or UV bursts from a natural source.

8. **Scattering Intensity** The scattered intensity is proportional to the incident intensity and to the square of the volume of the scattering particle and on wavelength. Hence, if an aerosol cloud exists (say at high altitude) and is radiated with a light source, the reflected light seen by an observer will be critically dependent on particle size. Long waves would be expected to be less effectively scattered than short ones because the particles themselves present obstructions to the waves, which are smaller (compared with the wavelength) for long waves than for short ones. The intensity viewed is proportional to $1/\lambda^4$. As red light (λ = 7200) has a wavelength 1.8 times as great as violet light (λ = 4000) the law predicts $(1.8)^4$ or ten times greater scattering for the violet light from particles much smaller than the wavelength of either colour. Hence, if white light is scattered from sufficiently fine particles the scattered light always has a bluish colour. If the size of the particles is larger, then the scattered light becomes whiter.

9. **Pollution** In passing it is suggested that the reported increase in atmospheric pollution (particularly over large cities) may have a bearing on the charged aerosol phenomena (reported at Working Paper No. 19) and thereby the increasing incidence of UAP reports. That there is a clear connection with the particles in suspension in earthquake and volcanic zones is reported elsewhere in the report.

SONOLUMINESCENCE

10. Sonoluminescence is the production of wide-spectrum light, visible by the human eye, due to the compression of gas

bubbles by sonic (i.e. sound air pressure) shock waves. While this can be easily reproduced under laboratory conditions under water, and the light emitted extends from IR to UV, covering the entire human eye spectrum, it is not clear whether the conditions could (perhaps exceptionally) exist in the atmosphere. If this is so, then sonoluminescence could be a candidate source for the very short UAP events (e.g. <1 second), which are frequently found when examining the UAP reports. Although it is some 60 years since the discovery of the effect little serious work on understanding and quantifying the phenomenon has been done - mainly because of lack of measurement technology.

11. The science behind the sonoluminescence effect can be summarized as:

- A very small volume must be present (appearing, for example, as a gas bubble (cavity) in water) which must contain a gas other than pure oxygen or nitrogen. However, even a 1% impurity is sufficient to invoke sonoluminescence.

- Successive rarefactions and compressions must be present for the gas to pulsate rapidly.

- The radius of the gas bubble will expand when the pressure goes negative (e.g. for a bubble in water the radius can typically change from 4 to 40 microns).

- The sudden collapse (Rayleigh 1917) reaches supersonic velocities (1.4 kilometres per second quoted), stopping only when the gas in the bubble reaches a 'hard core' minimum radius (when the molecules can get no closer together).

- Photons of several eV energy level are emitted, at which time the temperature is estimated as being in the tens of thousands of degrees K. At this point the bubble surface is reported to 'bounce', with a surface acceleration which exceeds millions of g, causing a non-linear amplification effect (focussing) of the energy

- Several alternative theories are currently proposed for the micro-detail of the effect. However it is clear that flash duration depends upon, among other factors, the intensity of the emission and the gas/water mixture. The **longest** flashes occur with the **brightest** emissions. The effect is also pressure dependent.

- There are close analogies with cavitation bubbles in sonar.

12. The fact that this effect can be seen by the unaided eye was perhaps first reported in the original version of EXODUS (20:18); where "and all the people **saw** the sounds". This was removed in later translations (presumably as being impossible!) If the sonoluminescence effect can be produced, even under exceptional conditions in the atmosphere, it may account for some UAP reports.

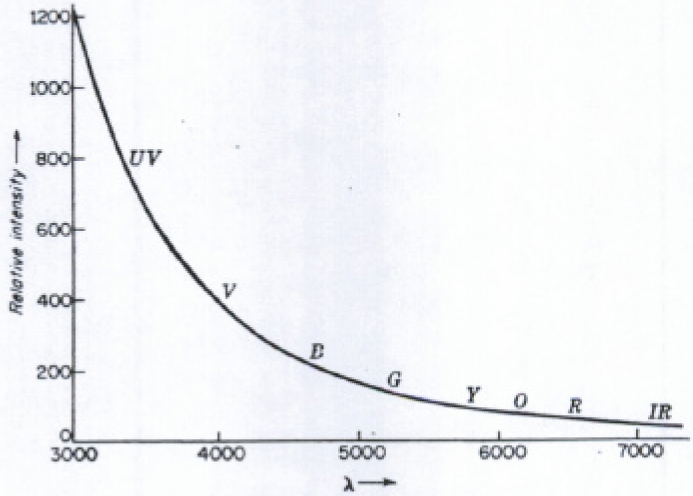

FIGURE 1: INTENSITY OF SCATTERING VS WAVELENGTH (RAYLEIGH'S LAW)

UK RESTRICTED
UNCLASSIFIED