VOLUME 3 - MISCELLANEOUS RELATED STUDIES

CHAPTER 1 - RADAR DETECTION OF UAPs IN THE UKADR

RATIONALE

1. An understanding of the capabilities and limitations of modern radars indicates that apart from the well-known radar interference from, for example, precipitation and wind-blown chaff (both RF dependent) and unwanted surface returns (clutter) the following interfering signals may also be received and displayed:

- [redacted] S.26

- **RFI/EMC** - Local electromagnetic effects can produce spurious returns. Some radars have filters to reject non-synchronous signals. The persistent types, which may, for example, affect fixed radar installations are usually identified and eliminated. Moving radars may encounter unexpected sources, while fixed stations may be affected by a moving interference source, only lasting a short period - hence, the possibility of producing what can appear to be a genuine target for a while. Moving plasma reflectors can produce realistic targets which can cross the detection threshold. The case of the spurious reflector located between the real target and the radar is particularly noted. The 'ghost' detection false velocities can be very high (compared with expected target speeds).

- **'Angels'** - although usually rejected, it is possible to receive and display far-distant surface returns due to the wave being partially reflected and partially refracted by atmospheric conditions. Temperature inversions cause thermal refractivity gradients (see also Working Paper at Volume 2, on optical 'mirages'). Similarly to the optical situation, the maximum confusion effect at radar frequencies is at very low elevation angles.

- **Birds** The radar echoing area (RCS) of birds and insects is of passing interest. It is only a few square centimetres and would normally fall well below the detection threshold of all but specialist radars; generic values are at Table 1-3.

(U)

2. **Anomalous Propagation** Radar signal propagation is normal in the UKADR for the majority of the time. It is possible, however to have atmospheric temperature lapse-rates where upward bending of the radar beam results in a reduction of the distance to the normal radar horizon. Dependent on the pressure-temperature gradient and partial pressure of water vapour, the extreme case is that of trapping the curved wavefronts to produce surface ducting. The mechanism of

ducting is somewhat different in tropical conditions than in temperate climates. For the purpose of evaluation of possible anomalous specular signals (which may be mistaken as UAPs), in the UKADR, inversion duct theory is used[1]. The effect can occur both in the radar's main beam and its vertical side-lobes. It is important to note that anomalous radar returns caused by the super-refraction form of this phenomena can take place in thunderstorm conditions - often also the scenario for 'ball' and 'bead' lightning and its consequent mis-identification as a UAP.(U)

3. [redacted] S.26

4. **Natural Conditions** The lower atmosphere is not a plasma under normal conditions. It contains 3 x 10^{25} electrically neutral molecules per cubic meter and only about 5 x 10^{8} ions. Ionising radiation accounts for ion pairs to be created all the time, balanced by the like number neutralised by re-combination. In fair weather, at sea level, there is an average downwards electric field force of about 130 volt.m^{-1}. An atmospheric layer at about 60km altitude is the lowest level in the atmosphere of uniform electrical potential (known as the 'electrosphere'). The potential of the electrosphere is ~300,000 volts positive with respect to the Earth's surface (i.e. the surface is the balancing negative charge).(U)

5. A current flows in the atmosphere because the air is not a perfect insulator. The charge balance (since the charge would otherwise leak away) is maintained by several hundred thousand lightning flashes per hour around the world. It is important to note that aircraft (flying at velocity (V) in the atmosphere), create their own electrostatic charge. They represent a conductor travelling in earth's magnetic field (β) and in fact generate a voltage between the extremities (e.g. for a Length L, Velocity V the potential is calculated from $E=\beta LV$). (U)

6. If the 'charged' aircraft encounters another charged body in the atmosphere it is assumed that the laws of electrostatics will apply and either an attraction or repulsion will occur. However, the aircraft will be moving at some velocity, whereas the 'UAP' can either be stationary or moving. Hence, there appear to be conditions where the charges do not come together, but reportedly parallel the aircraft course or follow it. When (conducting) flying vehicles enter a non-uniform field (E) a current dependent on $\partial E/\partial t$ arises in the vehicle. The balance of the charge with the UAP charge is believed to dictate the UAP subsequent motion. It is further reasonable to assume that the charged (phenomena) body may be either gaining or loosing energy hence it may dissipate and disappear.(U)

RADAR PERFORMANCE

7. Irrespectively of any other radar limitations, the ability to make an initial detection is fundamental. For radar reflections to occur from an atmospheric or any other type of plasma (as explained at Vol. 2 Working Papers Nos 21,19 & 5) requires the plasma to have a specific minimum electron density in the volume inspected by the radar beam. Reflection is dependent on the radar operating wavelength. [redacted] S.26

[1] Bean D.R. and Dutton E.J. "Radio Meteorology" US Govt. Printing Office, Washington

[redacted] S.26

8. The reflected power measured by a radar system is the average integrated power reflected from a finite illuminated area. If the reflecting area is smooth, with no irregularities, then the reflection will be entirely coherent and specular and a one-dimensional model can be adequate. However, if there are large spatial irregularities then the signal will be completely incoherent and diffuse. In between these extremes the reflected signal will contain both coherent and incoherent components, depending on the physical structure of the irregularities. In the context of the 'multi-cored' UAPs this seems likely to be the case. In the near field, from these diverse reflectors, there will be interference patterns and, potentially, considerable variability of reflected signal strength. The far-field value will be the residual signal resulting from the incoherent combinations.(R)

9. Since the plasma (or 'linked-plasmas' in a multi-core type UAP) will be, (according to witness reports of motion and colour change in the lights), in almost constant motion, it is reasonable to suggest that either regular or irregular field modulations could be present - not only in the self-radiation of the body, but in its radar-reflective properties. In basic terms, its RCS is likely to be fluctuating, probably for most of the time. This may not be the case where single-coloured ball lighting is reported which seems to be more stable than the multiple colour, multiple 'core' system that frequently form 'triangular', 'rectangular' or 'stacked' assemblies, often with an apparent shaped black coloured void between the bounding 'hot spots'. It may well be the case that quite apart from variable scatter from a large proportion of the total apparent reflecting area, that the variation of the reflectivity of the core itself may be below a particular radar's minimum detection capability.(R)

10. The scattering of EM waves from a variable surface has been long studied for more conventional radar targets. For a fluctuating plasma a number of variations will be evident dependent, for example, on the RMS coherent scattering coefficient, the RF in use, the ripple and curvature on the plasma surface, the electron density, correlation length, etc. Refraction effects, additionally, could cause smearing of the beam profile and absorption further weaken the radar returns, even if the electron density is theoretically adequate for the incident RF to be reflected under ideal conditions.(U)

11. [redacted] S.26

12. **Plasma Cylinders & Vortex Rings** Occasionally UAP reports describe a circular, cylindrical or 'boomerang' shape. These are sometimes oriented horizontally and sometimes vertically and various models are proposed. Entities are sometimes described as "a row of balls touching each other" or "a stack of discs one above the other"; the radius differs at various points along the 'cylinder' length. In some ways the resultant RCS can be expected to

be similar in format to a rocket plume. The distribution of the electrical properties (e.g. the electron density) are inhomogeneous both radially and axially.(U)

13. The modelling results [3] can only be an approximation, since the actual structure of the plasma UAP has never been measured. In the absence of any other information, it is assumed that a UAP (of the plasma type) comprises a plasma which obeys Maxwell's Equations. The important factors of a tubular-shaped plasma appear to be:

(a) In similarity to other radar targets the target response will vary with plasma 'cylinder' orientation and radar polarisation.

(b) The RCS varies with the incident radar's Radio Frequency.

(c) The RCS per unit length increases with the aspect angle, with the maximum RCS being reached near the cylinder centre.

(d) [redacted] S.26

14. For the purpose of the model, since total RCS is obtained by integrating lengthwise (in this case the length of the UAP); a radar range resolution of 100m is assumed. The numerical results were extracted (for the purpose of this DIS report) over a plasma cylinder radius of 0.4m and length of just over 1m up to a radius of 0.88 and length 122m.(U)

15. The set of results, shown at Figure 1-4, indicates a very small RCS per unit length, much less than 1m^2, depending on aspect and polarisation. It is assumed that very similar effects may be present from elongated rotating vortex rings if they were illuminated by radar energy (U)

Aircraft as a Charged Body

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[3] Shi Jiamming et al "Computation of the RCS of the Turbulent Plasma Cylinder" Inst. of Plasma Physics 43rd Inst. of State Ministry of Electronics PR China CIE Radar Conference 1996However, the aircraft will

be moving at some velocity, whereas the 'UAP' can either be stationary or moving. Hence, there appear to be conditions occurring where the charges do not come together but reportedly parallel the aircraft course or follow it. When (conducting) flying vehicles enter a non-uniform field (E) a current dependent on $\partial E/\partial t$ arises in the vehicle. The balance of the charge with the UAP charge dictates the UAP subsequent motion. It is further reasonable to assume that the charged (phenomena) body may be either gaining or loosing energy hence it may dissipate and disappear.(U)

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18. The reflected power measured by a radar system is the average integrated power reflected from a finite illuminated area. If the reflecting area is smooth, with no irregularities, then the reflection will be entirely coherent and specular and a one-dimensional model can be adequate. However, if there are large spatial irregularities then the signal will be completely incoherent and diffuse. In between these extremes the reflected signal will contain both coherent and incoherent components, depending on the physical structure of the irregularities. In the context of the 'multi-cored' UAPs this seems likely to be the case. (U)

19. In the near field, from these diverse reflectors, there will be interference patterns and, potentially, considerable variability of reflected signal strength. The far-field value will be the residual signal resulting from the incoherent combinations. Since the plasma (or 'linked-plasmas' in a multi-core type UAP) will be (according to witness reports of motion/colour change in the lights), in almost constant motion, it is reasonable to suggest that either regular or irregular modulations will be present - not only in the self-radiation of the body, but in it's radar-reflective properties. In basic terms, it's RCS is likely to be fluctuating, probably for most of the time. This may not be the case where single single-coloured ball lighting is reported which seems to be more stable than the multiple colour, multiple 'core' system that frequently form 'triangular', 'rectangular' or 'stacked' assemblies, -often with an apparent shaped void between the bounding 'hot spots'. It may well be the case that quite apart from variable scatter from a large proportion of the total apparent reflecting area, that the variation of the reflectivity of the core itself may be below a particular radar's minimum detection capability.(R)

20. The scattering of EM waves from a variable surface has been long studied for more conventional radar targets. For a fluctuating plasma a number of variations will be evident, dependent, for example, on the RMS coherent scattering coefficient, the RF in use, the ripple and curvature on the plasma surface, the electron density, correlation length, etc. Refraction effects, additionally, could cause smearing of the beam profile and absorption further weaken the radar returns even if the electron density is theoretically adequate for the incident RF to be reflected under ideal conditions.(U)

21. [redacted] S.26

SUMMARY OF UKADGE RADAR PERFORMANCE AGAINST UAPs

22. If, as seems quite likely, UAP phenomena is mainly caused by atmospheric plasmas (mis-reporting of man-made objects excepted), this phenomenon can be created by various natural causes for which examples are detailed in the Working Papers at Volume 2. The nature of plasmas has been studied in relation to their detectability by radar. [redacted] S.26

23. **Target Characteristics** Plasma characteristics are widely explored in Vol. 2. In relation to radar response:

- The nature of plasma as a radar target is that of an amorphous electrically charged mass, which can appear as a sphere or other shape, a collection of spheres usually up to five in close formation, often forming a 'tube' or 'cylinder', either horizontally or vertically stacked; or (in plan) forming a pattern (triangle is the most prevalent, but oblongs, diamonds and star shapes can be seen). All would (according to witnesses' assessment of size) fall within a single radar resolution cell of most EW radars . They could possibly occupy adjacent range cells of Airborne Interception (AI) radar.

- Some plasmas can reflect radar energy, others cannot, dependent on the incident RF angle and the plasma electron density.

- Plasma life is limited. Weakening internal fields, temperatures, change in pressure, etc., internal electrical forces, rotation of the body, make the plasma an ever-changing target.

- According to russian research the maximum broadside RCS, i.e. at 90 degrees orientation, (Figure 1-4(a) to (f)), even with optimum polarisation, is only of the order of 0dB ($1m^2$) and changes in aspect-angle can quickly reduce to as low in value as - 40dB ($0.0001m^2$). As seen at Figure 1-4 (e), as the RF increased, the RCS decreased for most aspect angles. (U)

24. **Radar Characteristics** [redacted] S.26

There are, however, several other key factors:

- [redacted] S.26

- **Radar Signature** Even though the RF conditions and plasma density conditions may be correct, the RCS of any given plasma may nevertheless be much too small to be detectable (see minimum detectable signal at Table 1-1) [redacted] S.26

Further, it is not clear whether a UAP plasma has the same characteristic as a contained plasma in a laboratory. The radar response (including lack of response) could be quite different if the multi coloured plasmas rep[orted have more than one density core. For example the RCS may be dependent on a major reflector and several smaller ones or have the effect of a larger but unstable reflector fluctuation with random or predictable minor orientations. [redacted] S.26 Hence, it can be seen that together with the other factors below a plasma (which is inevitably gradually decaying towards extinction) may only produce a radar reflection for a limited period, if at all.

- [redacted] S.26

[redacted] S.26

25. The search beam (with, say, an azimuth beam-width of 1.5 Deg.) takes ~40m.seconds to pass through the UAP target. However, the velocity of the target may be 10km per second, travelling some 400 metres in this scan time. If UAP travel is across the beam and the radar detection range, due to the small target size, is only, say, 20km, (at which range the beam is only ~525m wide), the actual beam velocity is also travelling (at that range) at over 13km per second. Hence, depending which way the target is moving, either the radar beam is chasing the target and just overtakes it or, if the target is moving in the opposite direction to the beam, the dwell time on the target is seriously curtailed, as the time-on-target could easily be halved. Either way a relatively small number of pulses hit the target. With a PRF of, say 265pps about 11 pulses are designed to hit the target in normal operation against aircraft. Against a UAP, not only is it a small target in all probability, it may only receive half the number of pulses which, integrated-up, may not reach a detection level. [redacted] S.26 Of course, this is taking a fast target as an example, with an assumed small RCS. Slower targets might be detected if their RCS and aspects were favourable.(R)

26. **Operator Procedures & Thresholds** [redacted] S.26

27. Several other factors are important:

- [redacted] S.26

- **Correlation** [redacted] S.26 Frequently, when a UAP is spotted from an aircraft (often civil air-traffic) it cannot be seen on the controlling CAA radar. There is only one UK event on the DIS record where 3 radar's (2 RAF and one CAA) had simultaneous contact with a UAP, which eventually faded and disappeared.

(C)

SUMMARY

28. [redacted] S.26 [The findings of this brief investigation into the reasons for the clear lack of radar reports on UAP activity - bearing in mind that hundreds of visual reports are currently received annually, can be compared with a Spanish Air Force UFO investigation, in which it is openly reported that between 1962 and 1990 only 20 cases were detected by radar, and only 7 of those lasted long enough to vector AD Fighters to the location. Spain had UAP peaks in the periods 1968-71, 1974-75 and 1979-81].(U)

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