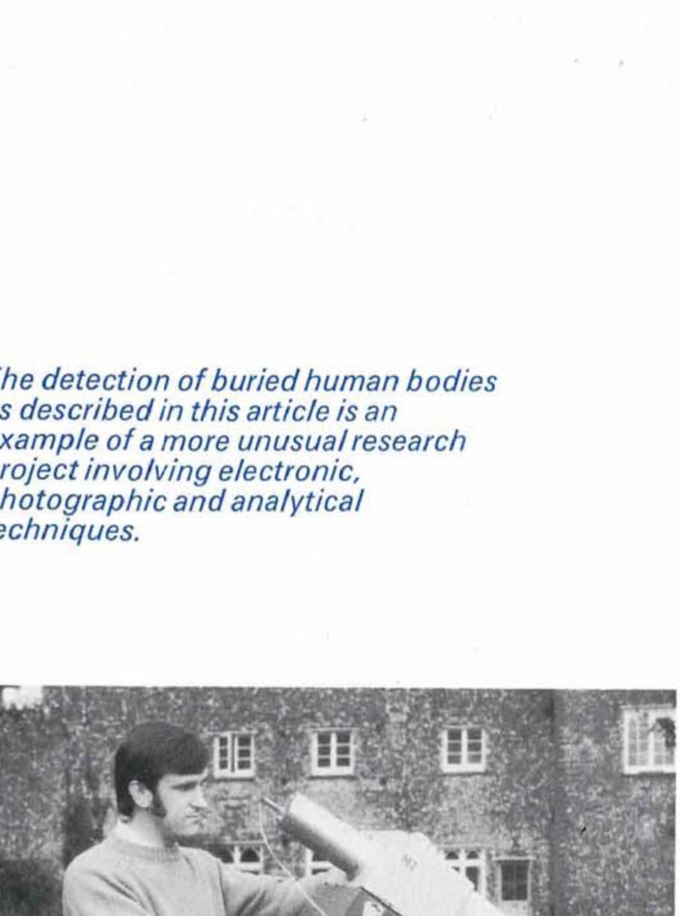
Cadaver detection – research to assist the police

by R J Drewett

The detection of buried human bodies as described in this article is an example of a more unusual research project involving electronic, photographic and analytical techniques.



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SINCE 1967 the Electronic Research Laboratory, now part of the Plessey Radar Research Centre at Havant, has been involved in research for the Police Scientific Development Branch of the Home Office, aimed at assisting the Police with various detection problems. Among these is the difficult task of searching for suspected buried or concealed bodies resulting from murder or accident. The approach has been to consider various types of search, the basic division being according to the size of the search area, and to investigate all the possible techniques which may be used to assist the search. So far, two prototype instruments have been supplied to the Home Office for evaluation; both these instruments are designed for small search areas and they are briefly described below.

Very often, however, the prospective search area is large—perhaps of several square miles. Even using a technique capable of detecting the body, the task of searching such an area is formidable. At present a manual ground search, using large numbers of men and perhaps dogs, is the only available technique. The cost of such an operation may well be hundreds of thousands of pounds. Current research work is aimed at developing a photographic system which can provide rapid imagery of an area under suspicion, and which may be used to plan the search. At present, trials using a technique known as multiband photography are being carried out, and the main part of this article deals with the research programme required to design the photographic system.

SHORT-RANGE DETECTION

Two prototype hand-held instruments have been produced for searching small areas. The first uses the fact that disturbance of the soil, and the presence of a burial, both tend to produce an anomaly in the electrical properties of the soil. An anomaly in soil permittivity may be detected using a small UHF transmitter and receiver. In the instrument the two transmitting dipoles and one receiving dipole are placed in the search head. By driving the transmitters in antiphase, zero signal at the receiver is achieved

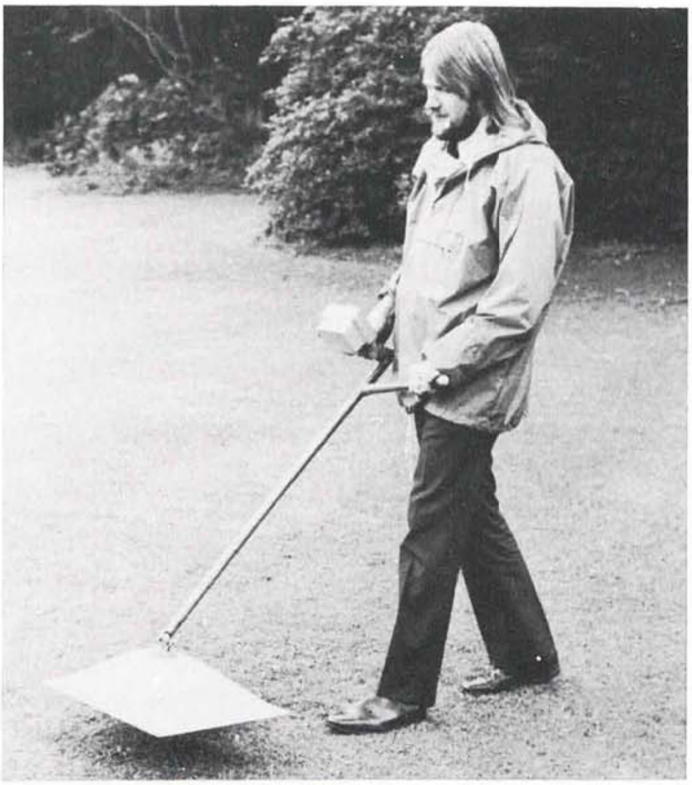


Figure 1. UHF detector in use

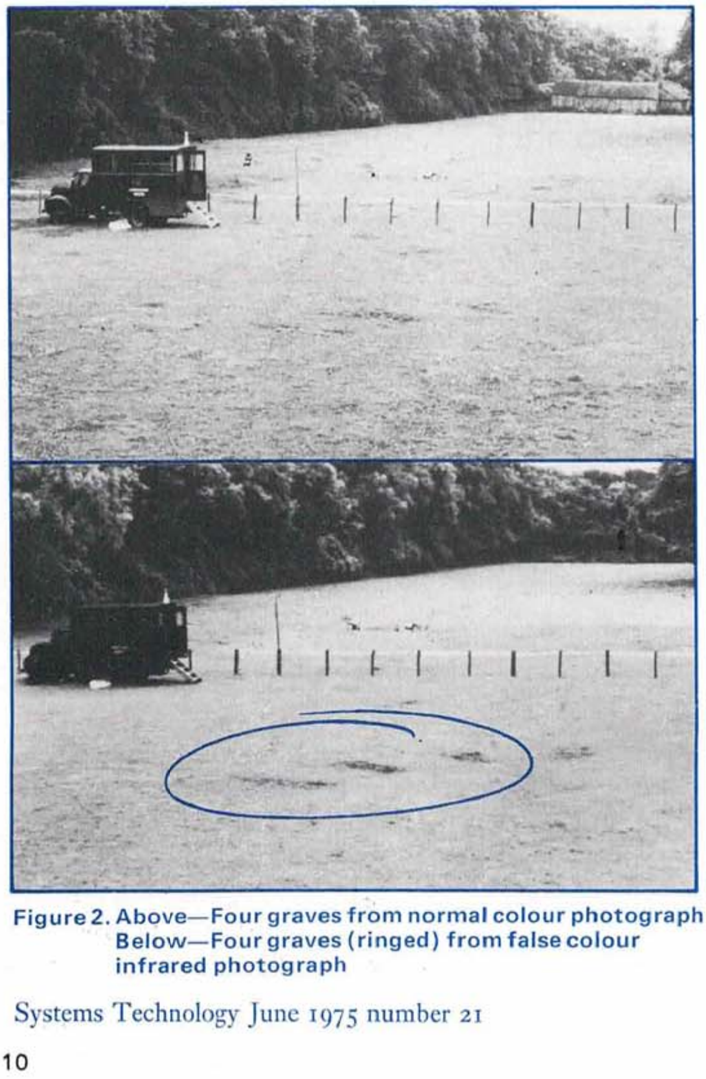


**Figure 2. Above—Four graves from normal colour photograph
Below—Four graves (ringed) from false colour infrared photograph**

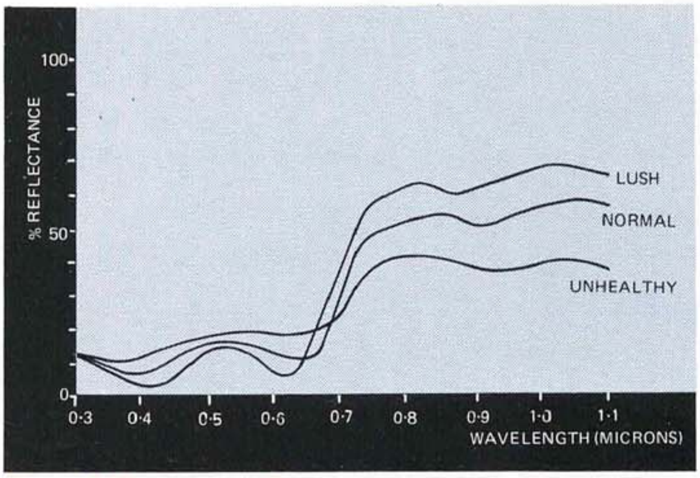


Figure 3. Vegetation reflectance

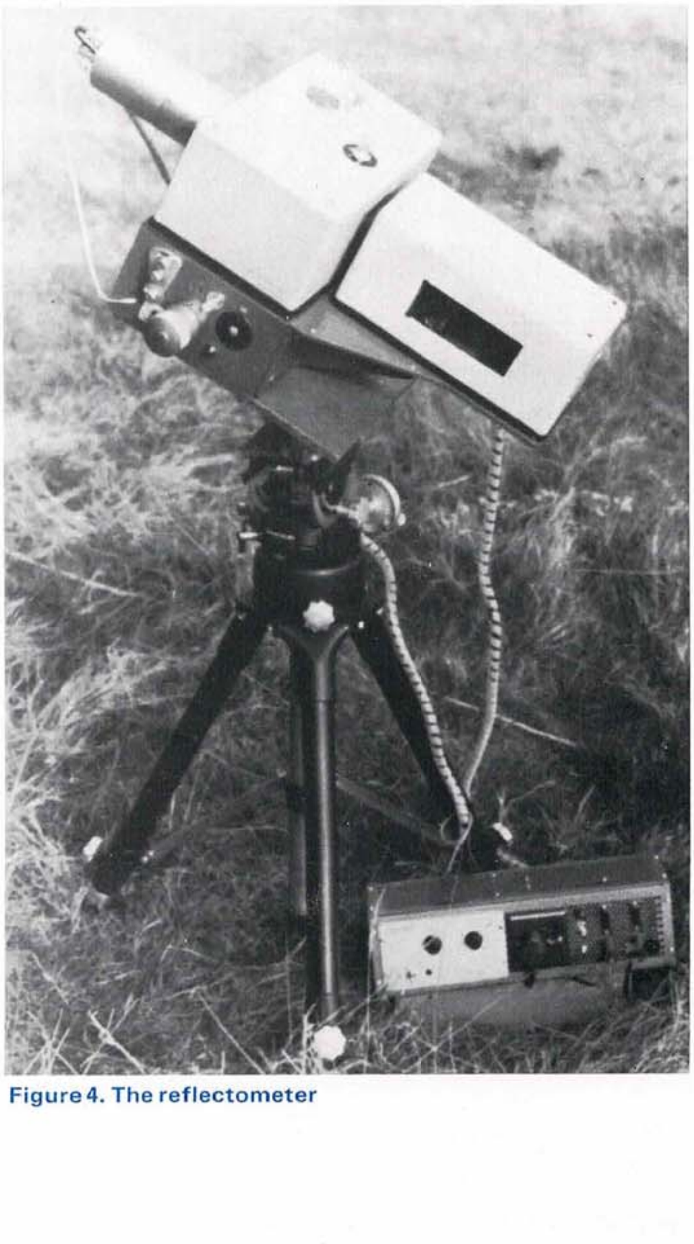
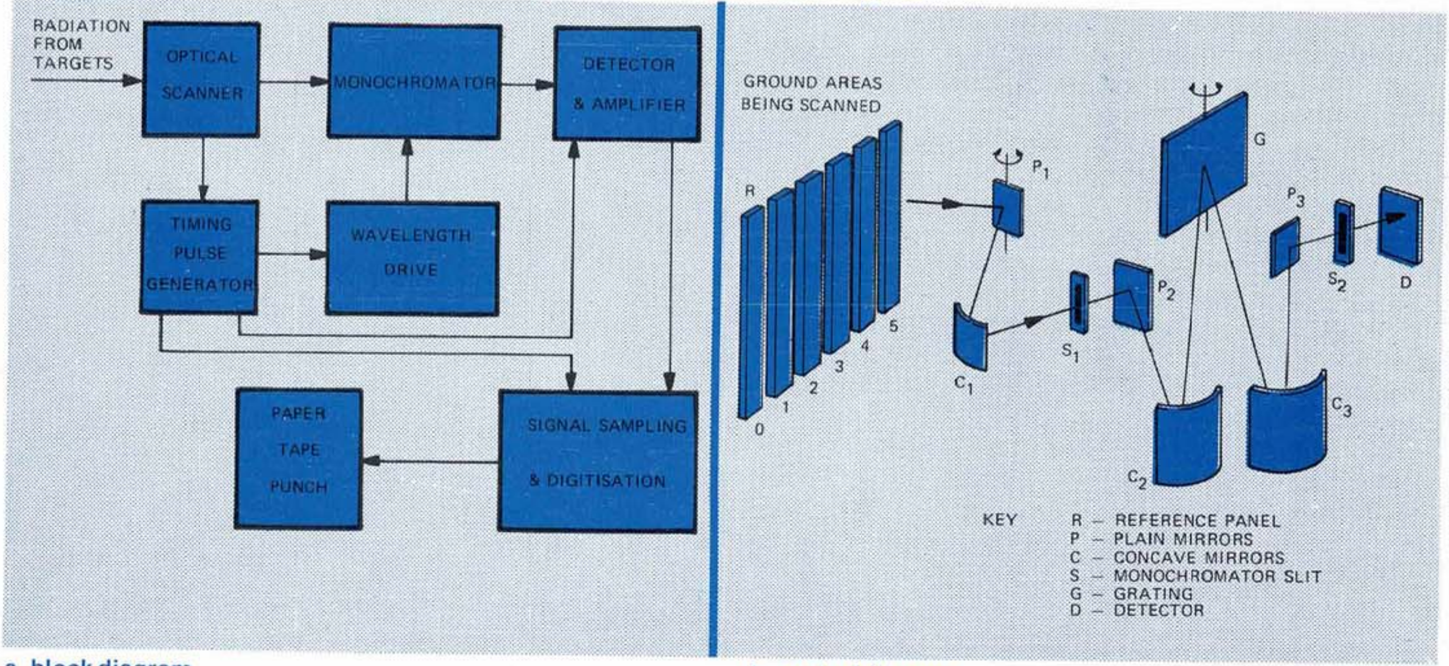


Figure 4. The reflectometer

Figure 5. Reflectometer principles



a. block diagram **b. optical diagram**

with the instrument held over uniform soil. Permittivity anomalies cause an unbalance as the instrument passes over them, and this is presented to the operator as a note of varying pitch. Figure 1 shows the instrument in use.

A second instrument relies on seismic anomalies for detection of a buried body. Normally a reduction in the natural resonant frequency of the soil takes place when it is disturbed, and a soft burial further enhances this effect. The instrument operates by applying a controlled impulse to the soil with a probe and detecting the resulting vibration with an accelerometer mounted on the operator's foot. The dominant frequency of the vibration is then measured and an output given when it falls below a preset threshold. The threshold is variable to accommodate different soil types. In trials this instrument has proved very reliable in detecting the grave area and has a low false-alarm rate.

Both the above instruments would speed the search rate for small areas and, subject to further trials, may be developed for operational use in the near future.

LONGER RANGE PHOTOGRAPHIC SYSTEMS

The aims of a photographic system to assist in a large-scale search are twofold. Firstly, the photographs should enable the search to be concentrated in the most likely areas; secondly, if possible, the target should be sufficiently detectable against the background as to give a high probability of detection and a low false-alarm rate.

Initially, a survey of currently available colour and panchromatic films was made, and trials were carried out on graves containing pig carcasses—known to decompose in a very similar way to humans. It was soon apparent that a large number of variables affect the appearance of the grave—including age, burial depth, weather, vegetation and soil type, and directions of illumination and view. It was found that under some conditions a film known as false colour infrared (FCIR) gave better contrast between grave and surroundings than any other colour or panchromatic film. The FCIR film has three emulsions sensitive to the green, red and near-infrared bands of the spectrum, with corresponding image colours of blue, green and red respectively.

Healthy vegetation has a high infrared reflectance, and therefore appears red on the film, while soil and unhealthy vegetation appear blue and magenta respectively. These factors produce enhanced contrast for recent burials. In the actual colour photographs the improvement is quite striking and while black and white cannot reproduce the effect, figure 2 attempts to indicate the type of difference between a normal photograph and one using false colour infrared. For older burials, where vegetation has regrown and may be lush due to nutrient-rich decomposition products, neither colour, panchromatic nor FCIR films are able to show the target adequately.

The next phase of the work was to measure the reflectance spectra of many different grave and non-grave areas in order to isolate any specific areas or bands of the spectrum which give contrast between the two target classes under a wide range of conditions; the eventual aim was a photographic system which could make maximum use of any such spectral bands. Typical grass reflectance spectra, somewhat idealized, are shown in figure 3 to illustrate changes that occur with varying health. Measurements of actual spectra were made over a period of nine months in 1973, covering a wide range of burial ages and environmental conditions, using a purpose-built remote scanning reflectometer (figure 4).

Spectral Signatures. Figures 5a and 5b show the block diagram and optical diagram respectively of the reflectometer.

For test evaluation/calibration, six ground areas (0 to 5), roughly one metre by 15 centimetres, are scanned sequentially by an input telescope; light is then reduced to a narrow spectral band by the monochromator. Rotation of the grating, G, changes the central wavelength and thus scans the spectral region. In normal use the instrument measures at 128 wavelengths in one of two ranges: 0·3–1·1 microns or 0·4–2·4 microns. For photographic studies the first range would be used since normal emulsions are sensitive between 0·4 and 0·9 microns (visible and near infrared). At each wavelength the detector signal from each ground area is recorded digitally for later computer input.

One of the six areas would normally be occupied by a white reference board of known reflectance (Channel 0); Channels 1 and 2 would be undisturbed vegetation while Channels 3, 4 and 5 would be in the target area. The target may be a grave, a control (disturbance to the same depth but without a burial), an anomaly (e.g. a lush area known not to be a grave) or a normal undisturbed area. Many measurements of each type of target were made, and the environmental conditions carefully recorded. In addition to the spectral reflectance data, measurements of solar angle, cloud cover, time of day, light intensity, vegetation and soil moisture were made and recorded in coded digital form.

Data Storage and Display. Data from the reflectometer, and coded information about the conditions associated with each run were recorded on punched paper tape. Using a DDP516 computer, data was input and stored on magnetic disc, which provided rapid access for analysis—all the data collected, about 150 runs each containing six spectra, could be stored on one disc. The original tapes and a master copy disc provided adequate backup in case of accidents.

The first aim of the analysis was to view the spectral signatures in a rapid and convenient way, using a visual display unit (VDU) as the computer output. A set of programs, operated by typing commands on a teletype input, were written as shown in table 1.

Using the display programs, a careful study of the data showed some interesting trends. Firstly, despite the high variability of the spectra, comparison of mean values showed that there were

A	EDITING	Allows recall of any trial, display of signal against wavelength, and editing to remove unwanted signals or to smooth undue noise
B	SUBSETS	Allows a subset of total available trials to be selected according to defined conditions, and set in separate file for display
C	DISPLAYS	One of four normalizations as follows, each plotted against wavelength in nanometres (1 micron = 1000 nm) ● Sensor signal: as recorded from detector, (figure 6) ● Standardized signal: selected channel plotted as percentage of white reference signal from channel 0 (figure 7) ● Percentage difference in reflectance: selected channel plotted as percentage of any other channel (figure 8) ● Absolute difference in reflectance: difference between two chosen channels as seen in second display. Each display may be from a single trial, or shown as the mean of a chosen subset of trials. Displays of the same type may be superimposed.

Table 1. Display programs for analysing reflectometer results

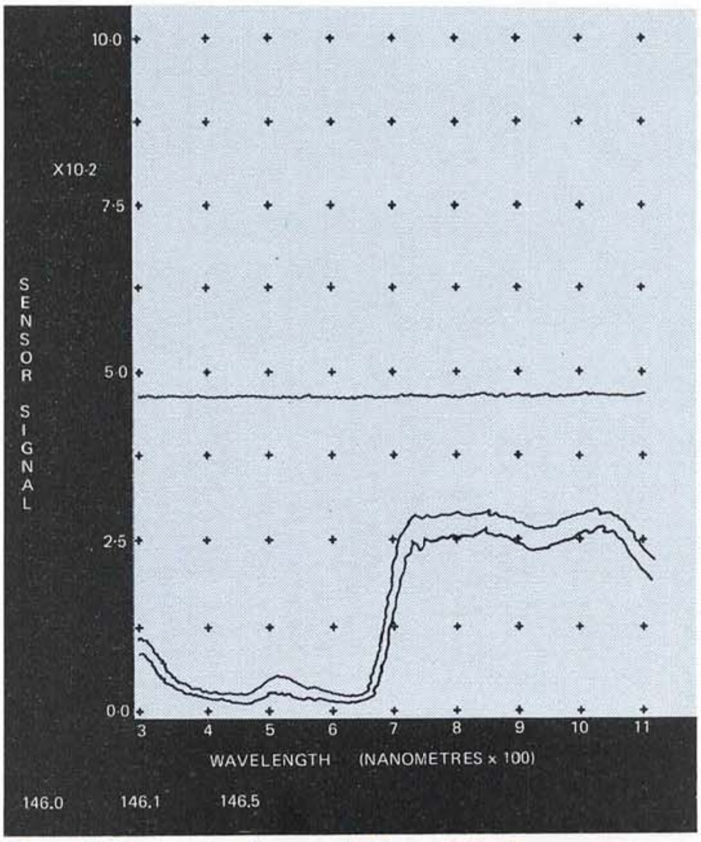


Figure 6. Sensor signal, recorded from detector

several spectral regions where consistent differences were seen between grave and non-grave target reflectances. Secondly, the bandwidth of these effects was quite small—often about 50 nanometres—when compared to that of colour photographic emulsions (typically 150 nm). An example of such an effect is seen in figure 6 at about 675 nanometres (deep red).

From these observations, a number of features derived from the spectra were proposed—typically, these were mean reflectance values within a specified narrow band. Each feature was then tested for its ability to separate grave and non-grave targets. Further, the performance of sets of features was tested using the weighted sum evaluation (WSE) program, which evaluates the ability of each feature to separate the two classes of spectra, and assigns to each feature a probability of error (POE). The lower this value, the better the feature. The feature with the lowest POE is the first in the set. The next feature is chosen also to have a low POE, and also a low correlation coefficient (CC) with the first feature. By repeating this procedure a set of features can be built up and having proposed a set of features, its performance in discriminating between classes of spectra can be evaluated.

As an example, suppose that three features are taken from the available reflectance spectrum:

F1 : mean reflectance 450–500 nanometres
F2 : mean reflectance 550–600 nanometres
F3 : mean reflectance 625–675 nanometres

The reflectance of each target is now described by a set of three numbers which are the three feature values.

Discriminant Analysis. This is a means of testing whether

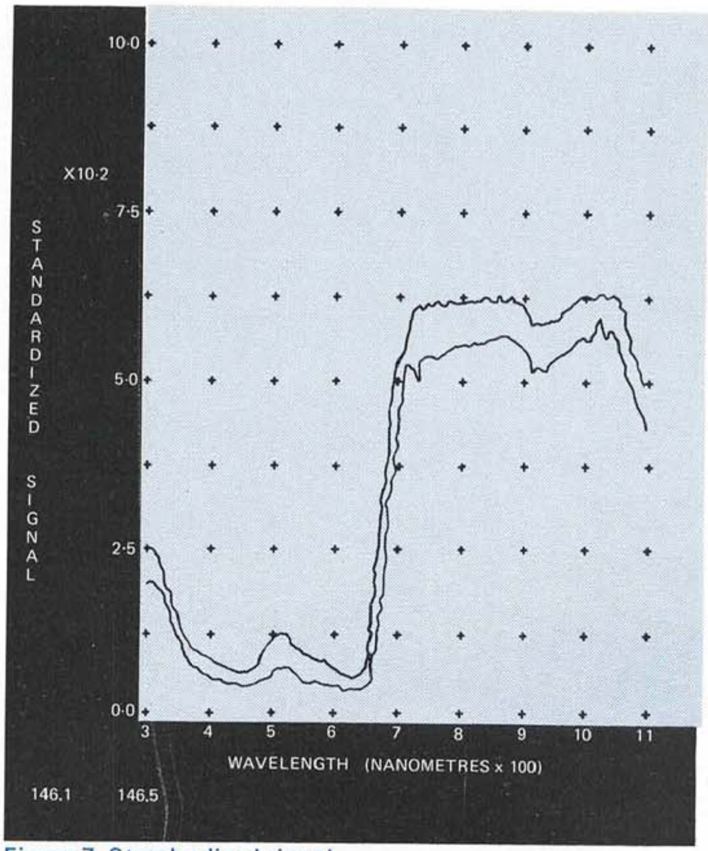


Figure 7. Standardized signal

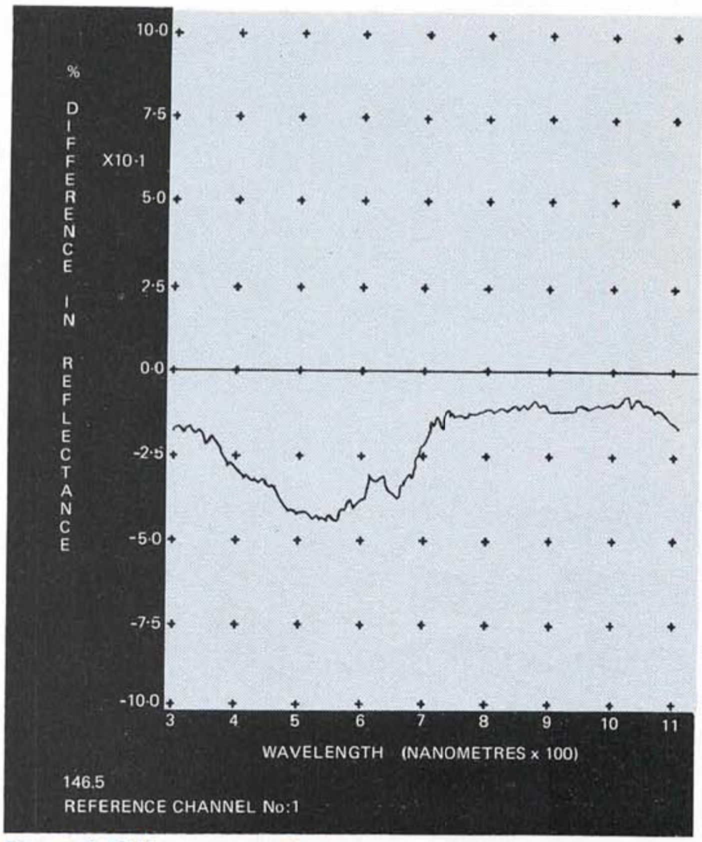


Figure 8. Difference spectrum

chosen feature sets can be used to separate the target classes. First, a three-dimensional co-ordinate space with axes F1, F2, F3 is set up in the computer; each curve is then plotted as a single point in the space and identified by a symbol. In our case, we call grave spectra 'x' and non-grave spectra 'o'. If the chosen features are significant, the two classes will tend to group together, each group centred about a different point in the space. The level of discrimination achieved is given by the amount of overlap between the two groups. A convenient method of viewing the scatter plot is by Fisher-Sammon mapping, which reduces the original space to two dimensions while keeping the grouping and class separation which was present. An example of the Fisher-Sammon map is shown in figure 9. Here, a boundary is drawn to separate the two classes and each part of the space is labelled; the area within the boundary is labelled non-grave (symbol 'o') and the area outside it is labelled grave (symbol 'x').

By counting points in each part of the space, a measure of the success rate is obtained, usually expressed as a percentage of the total for each class. Normally this process would be applied to a representative selection of the data, known as the training set (figure 9a). The bulk of the data, divided into test sets, would then be subjected to the same procedure to measure the classification performance and an example is shown in Figure 9b, where the symbol '1' represents grave spectra not used in setting up the boundary.

The Discriminant Analysis procedure was carried out on several feature sets, including that given as an example; the test sets used were grave (G), normal background (B), control grave (C) and lush anomaly (L). The best feature set gave the following results:

Test Set	G	B	C	L
Class	G	NG	NG	NG
% Correct	72	80	72	78

NG = non-grave

These results were very encouraging, and suggested that a photographic system using such a feature set would give a performance better than standard fixed-emulsion films.

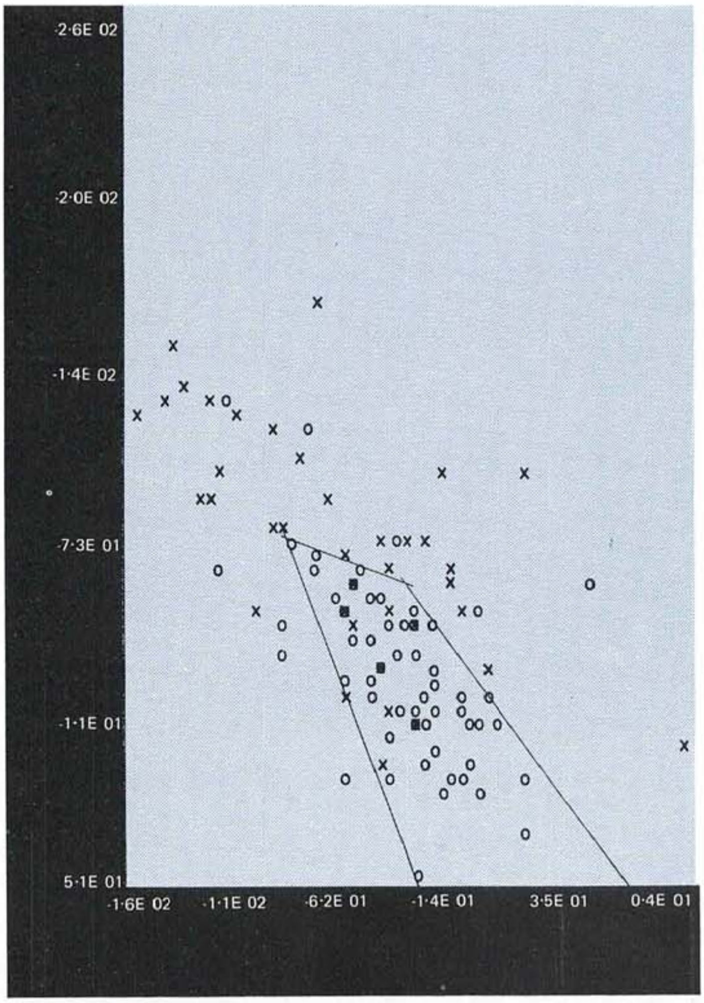
MULTIBAND PHOTOGRAPHY

Current work is aimed at designing and testing an aerial photographic system which makes use of the optimum feature sets found from the spectral analysis. Each feature is simulated using an optical interference filter which passes only a narrow light bandwidth through the camera lens to form an image on panchromatic film.

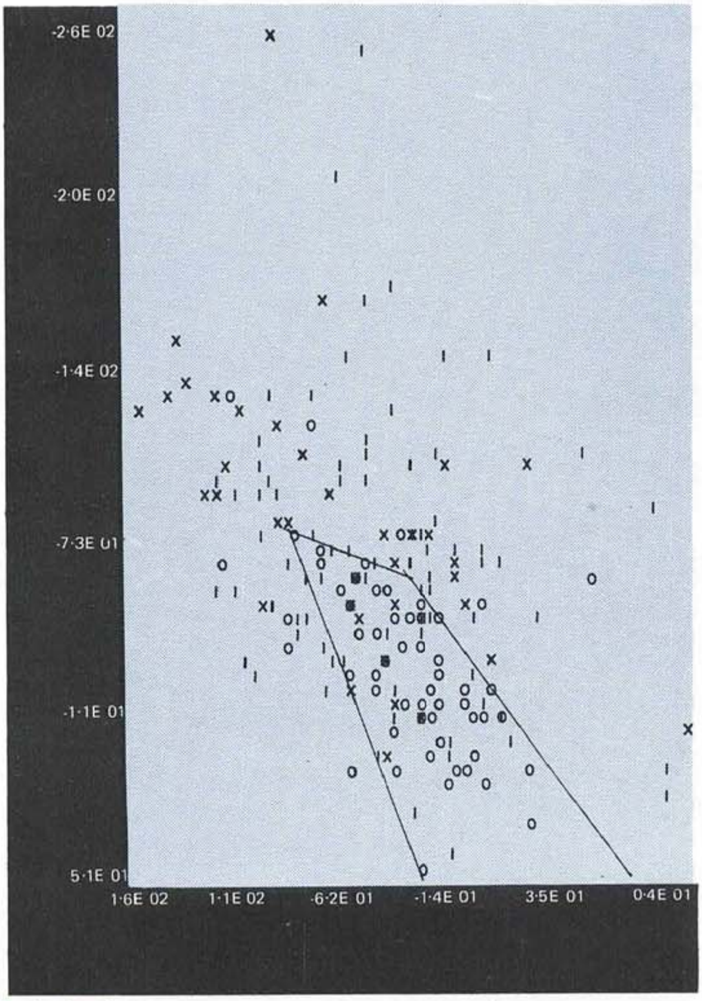
Using a four-camera array, simultaneous images of the test area are recorded through four filters which form a feature set. For the trials, the cameras are mounted on an autogyro as shown in figure 10. This aircraft has the advantage of extreme flexibility and low cost. Test sites on three different terrain types have been set up, each containing several burials of differing ages. Each site is flown regularly about once per month using a series of filter sets.

In order to simulate the computer analysis, the images are then combined in a purpose-built viewer. In this instrument, up to three negative images are superimposed in register on a screen; each negative is illuminated via an infinitely variable colour filter system, which allows the operator to vary the colour balance of

Figure 9. Discriminant plot (using Fisher-Sammon mapping)



a. training set



b. test set

the resulting image to maximize the contrast between the grave areas and the undisturbed areas.

CONCLUSION

It is clear from the research programme to date that the problem of locating buried bodies is extremely difficult and complex. Some considerable progress has been made towards developing both short-range and long-range searching systems, but many problems remain before an operational capability is achieved. However, the results of the research programmes described do seem able to provide scientific approaches worthy of further evaluation.

ACKNOWLEDGEMENT

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Figure 10. An autogyro used for aerial photography (cameras ringed)