

Creighton Rees - 1910564 - RS&I Assignment Part 1 & 2B

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Submission date: 12-Jan-2024 02:48PM (UTC+0000)

Submission ID: 221760882

File name: 18048_Creighton_Rees_Creighton_Rees_-_1910564_-_RSI_Assignment_Part_1__2B_542402_1030608072.docx (6.1M)

Word count: 3705

Character count: 20091

Remote Sensing & Imaging

Assignment Part 1 & Part 2b

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M6X00945: Remote Sensing & Imaging

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Part 1A

1. Introduction

1.1. It has been asked that a report be produced detailing the methods available for the acquisition of raw data implementing Remote Sensing & Imaging (RS&I) on a littoral zone within a friendly urban area. The information collected must include the topography of the area above the neap lowest astronomical tide chart datum, including local structures and accessways within 250 metres of the mean sea level to a resolution of 15cm. [1]

1.2. The scenario chosen for the purpose of this report is that a large defence company are looking to build a new underground munitions test facility. The intention is that the test facility is near a littoral zone so that underground test tracks can be made which run out beneath the coast. This will reduce the hazard to nearby urban areas increasing the number of possible sites to investigate for the facility.

'Remote sensing is the acquiring of information from a distance. NASA observes Earth and other planetary bodies via remote sensors on satellites and aircraft that detect and record reflected or emitted energy. Remote sensors, which provide a global perspective and a wealth of data about Earth systems, enable data-informed decision making based on the current and future state of our planet.' [2]

1.3. There are three main domains to consider when acquiring RS&I data, these are: ground-based, airborne, and spaceborne. Each domain implements specific platforms equipped with appropriate sensors to capture data within that environment and distance from the target object, Figure 1 [3] below shows an illustration of typical RS&I platforms and their operating altitudes.

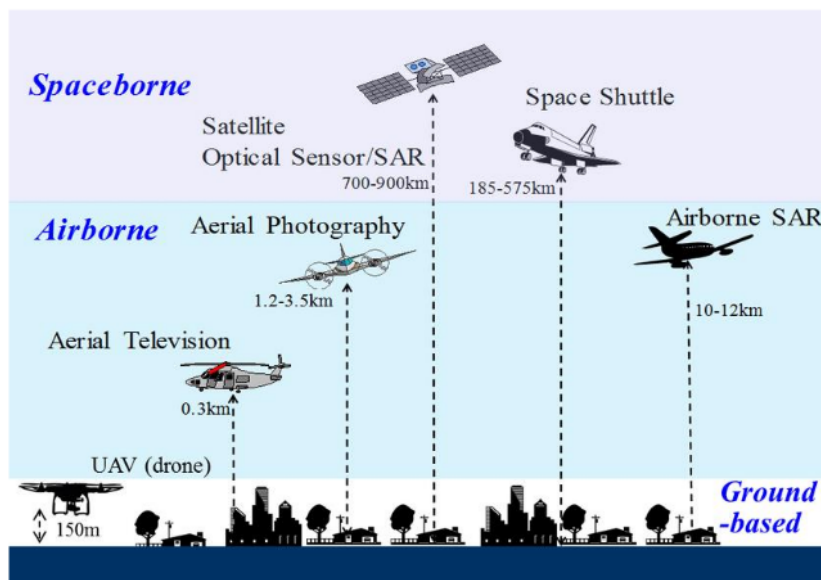


Figure 1 – Typical RS&I Platforms & Operating Altitude [3]

- 1.4. The principles behind obtaining the data by using sensors, scanners and cameras are common between platforms, although operating parameters to ensure appropriate quality and controls to prevent data loss or distortion of data can vary substantially between platform and sensor. Additionally, the quantity of raw data gathered using each platform can vary, data storage and the level of processing required should be considered as these aspects impact heavily on the cost associated with the data acquisition.
- 1.5. Any approach and platform used to obtain the raw data, will need to be processed and georeferenced using Geographic Information System (GIS) software. This will allow for manipulation and visualisation of the raw data for interpretation. The benefits, limitations and ultimately the suitability of each approach to obtain the data required will be discussed in this report.

2. Options for data acquisition

2.1. Ground Based Platform

- 2.1.1. Using a Land Surveying Tripod equipped with a Light Detection and Ranging (LiDAR) Scanner, the required data set could be obtained. Typically, ground-based scanners are categorized by range, short (<1m – 200m), medium (300-800m), and long (~2000m).
- 2.1.2. LiDAR scanners operate within the near infrared region of the electromagnetic spectrum and are active sensors, which means that the scanner emits the energy required for reflectance in the form of a rapidly pulsating laser beam. Unlike passive sensors which do not emit any energy for analysis, they use the energy reflected from an external source, typically the sun. [4]
- 2.1.3. LiDAR scanning coupled with high resolution cameras allow for precise X, Y, Z, coordinate data to be computed from the survey area which in turn can be used to produce accurate 3D models for visual interpretation, there are three key datasets required to achieving this computation.
- Firstly, by accurately calculating the time it takes for one pulse of the laser to be sent, reflected from the earth or objects surface, and returned to the detector, typically a photodiode*. This is referred to as its Time of Flight (ToF)
 - Secondly, by determining the angle of which the pulse was emitted.
 - Finally, by determining the absolute position of the sensor relative to the ground. This is achieved by using accurate Global Positioning Systems (GPS) [4]

**Photodiode accepts light energy as input to generate electric current. [5]*

- 2.1.4. LiDAR scanners can have a sample rate of up to 150,000 pulses a second, therefore a substantial amount of data is created with each survey. This will demand computer systems with high processing capabilities, and large storage capacity, to manage the

level of raw data generated, this dataset will produce what is known as point cloud data [4]. Figure 2 [6] below shows a typical representation of LiDAR point cloud data when captured from an elevated ground-based platform.

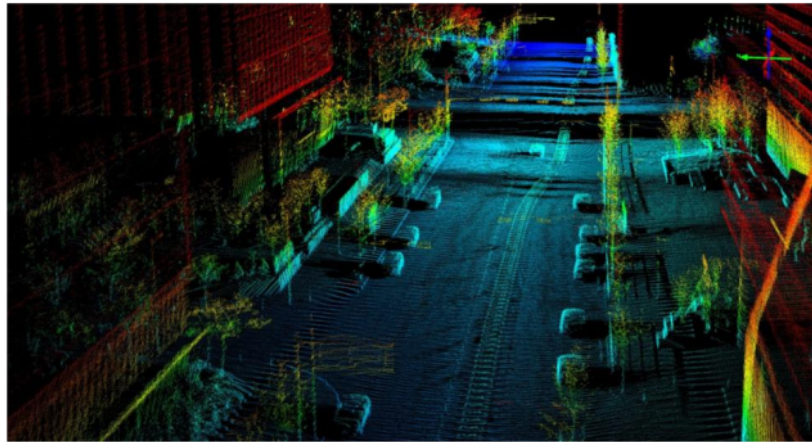


Figure 2 – Typical representation of LiDAR point cloud data from an elevated ground-based platform [6]

2.1.5. The benefit of using this method to obtain the data required is that the accuracy of the data in terms of resolution is far superior to the other sensing platforms. Using appropriate software, such as QGIS, the data gathered would allow for 3D representations of the point cloud data in the form of Digital Surface Models (DSM) or Digital Elevation Models (DEM) and Digital Terrain Models (DTM) this will be discussed further in Section 3.

2.1.6. This will allow senior management to visualise the site as it is at the time of the survey, including elevation of the ground and surrounding buildings to the briefs specified resolution of 15cm. Additionally this method of acquisition can be used during the day or night.

2.1.7. One considerable limitation to this method of data acquisition is that the process of obtaining the raw data is relatively slow. It would require a team of engineers to attend the site with the ground surveying equipment and physically set up the equipment at multiple locations along the survey area. It is crucial that throughout the data capture the scanners Field of View* (FoV) overlaps when sampling, this will prevent any 'blackspots' or areas of data loss.

**Field-of-view (FOV) is defined as the angle which is covered by a sensor. For LiDAR applications this is equal to the angle in which LiDAR signals are emitted. [8]*

2.1.8. As the suggested site is near a littoral zone the feasibility of acquiring a complete or continues dataset for the survey area from the ground is unlikely due to issues such as unstable ground or the inability to ensure that the scanners FoV consistently overlaps. Another limitation to this method of acquisition is that it can be dependent on weather conditions, it does not perform as well in cloudy or misty conditions as this can cause scattering or distortion to the data. [9]

2.2. Airborne Platform – Unmanned Aerial Vehicle (UAV)

2.2.1. Aerial Photogrammetry* AP (AP) could be a viable option for gathering the required dataset. The basic principle behind aerial photogrammetry is to mount a high-speed camera with high resolution to an aircraft, in this case a UAV, and take multiple overlapping images of an area beneath its flight path to generate 3D geometrical data.

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena. [10]

2.2.2. There are multiple benefits to using this method for data acquisition, there are many reasonably priced drones available with suitable photographic equipment capable of conducting the survey in a very short period with accurate data capture. Additionally, the images captured are permanent, at the time of capture, unedited or manipulated by processing software prior to interpretation reducing the possibility of anomalies within the data and allow for a re-review of the data. [12]

2.2.3. AP by drone can produce highly accurate 3D models as seen below in Figure 3 [13]. As the FoV of the camera is directly link to the altitude of the UAV, this allows for simple tailoring of the flight plan to suit the level of resolution, detail, and, accuracy required by the viewer, in this case 15cm resolution is easily achievable.

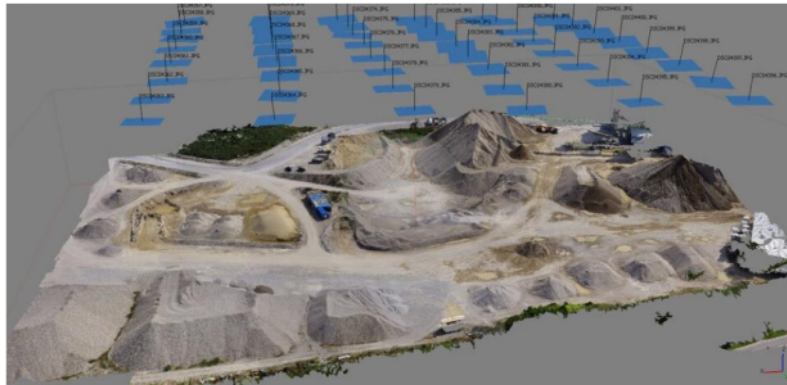


Figure 3 – Typical 3D rendering of AP processed data acquired by UAV [13]

2.2.4. Another considerable advantage to AP using UAV is the possibility to survey areas difficult or impossible to reach from the ground. In this scenario, a complete view of the survey area can be obtained without any obstructions or obscurities, by the pilot from a safe location. Additionally, only one licenced UAV pilot would be required to conduct the survey, unlike the ground-based platform discussed in Section 2.1 of this report.

2.2.5. One of the biggest limitations to using this method of data acquisition, is that the survey must be conducted in the presence of light, or during the day. The data gathered does not have the ability to penetrate any vegetation or for example

snowfall, so consideration of the time of year the data is intended to be obtained is required, as this can greatly affect the features visible within the survey area. [12]

2.3. Spaceborne Platform – Landsat 9

- 2.3.1. Landsat 9 is a sun-synchronized near-polar orbiting satellite equipped with two key sensors for data capture. One of the instruments it utilizes is the Operational Land Imager 2 (OLI) which takes measurements in the short infrared, near infrared and visible portions of the electromagnetic spectrum. Additionally, Landsat 9 is equipped with the Thermal Infrared Sensor (TIS) 2, which uses principles of quantum physics to measure emissions of infrared energy. [14]

A Sun-synchronous orbit (SSO), also called a helio-synchronous orbit) is a nearly polar orbit around a planet, in which the satellite passes over any given point of the planet's surface at the same local mean solar time. [15]

- 2.3.2. The OLI2 implements a passive sensor, as discussed in para. 2.1.2, which is known as a push broom scanner, this is because the data is gathered in lines like a push broom using linear detector arrays. [14] An illustration of this method of data gathering with the hardware used for acquisition has been shown below in Figure 4 and Figure 5 respectively.

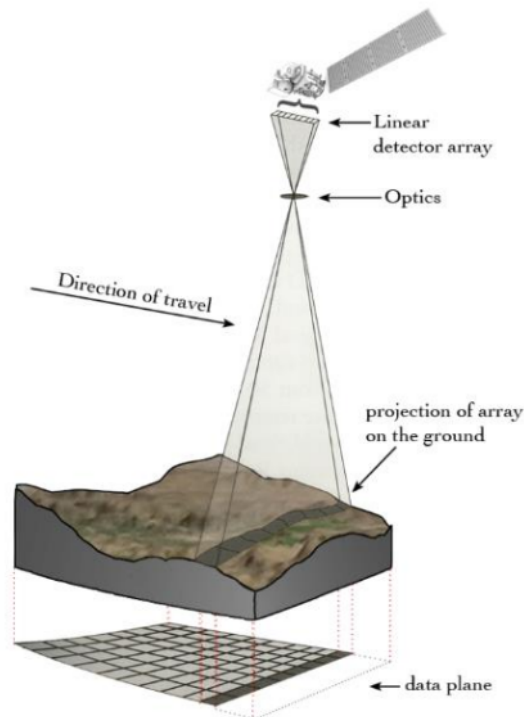


Figure 4 – Illustration of Push broom sensor Hardware [14]

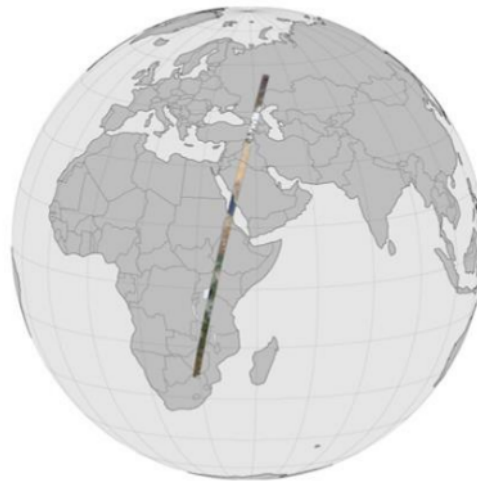


Figure 5 – Visualisation of the method of data collection [14]

2.3.3. The energy is a wavelength of electromagnetic radiation, which when reflected from a surface loses some of its energy through absorption, each surface or material will have a specific reflectance wavelength which is known as its spectral signature. Figure 6 below shows a graph of typical surface reflectance percentages against wavelength.

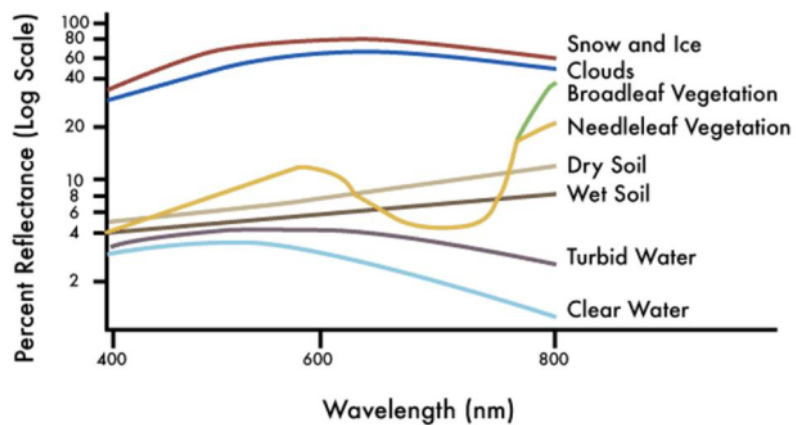


Figure 6 - Graph of typical surface reflectance percentages against wavelength

2.3.4. Using this information an accurate visualisation of a surface can be made from thousands of miles away, covering large areas in each sample run. The benefits to this method of data acquisition are clear to see, where rough terrain or inhospitable environments prevent data acquisition this is no issue or disruption to civil air traffic when using a spaceborne platform.

2.3.5. Spaceborne platforms can also maintain a geo-synchronized* orbit, meaning their point of observation is fixed allowing for constant observation of a given location. Additionally, there is the possibility of adjusting an orbit to enable a full view of the entire earth over a given period, in the case of Landsat 9, every 16 days [14].

2.3.6. One of the biggest limitations of RS&I using satellite borne platforms is cost. Initial costs to launch satellite into low earth orbit are exceptionally large when compared to any other method of data acquisition. In addition to the initial launch cost, the amount of data generated every second and the subsequent processing and storage requirement of that data is substantial, for some large projects this could mean hundreds of terabytes. [16]

2.3.7. For this assignment and the data required by the business, this method of acquisition would be partially suitable. As Landsat data is open to the public the required data set could be obtained without the need for physically attending the site. Although, the senior leadership team need a resolution of 15cm, this is beyond the capabilities of 'commercial' satellites, 15m is the special resolution specified for the Landsat 9 OLI2. [14]

3. Data Processing

3.1. The raw data gathered using the platforms outlined above will need to be processed further to allow for visualisation and analysis of 'usable' data, but before this can take place the data must be validated and checked for errors, this may be through validation or specific data cleaning programmes. Each platform will have its own specific methods of processing the data through complex computations.

3.2. DSM and DTM differ in that DSM shows the observed surface 'as seen' by the scanner which includes surface features like vegetation and buildings, where as a DTM allows the removal of these features and shows the actual terrain or bare ground of the survey area, this can be seen in **Error! Reference source not found.** [7] below.

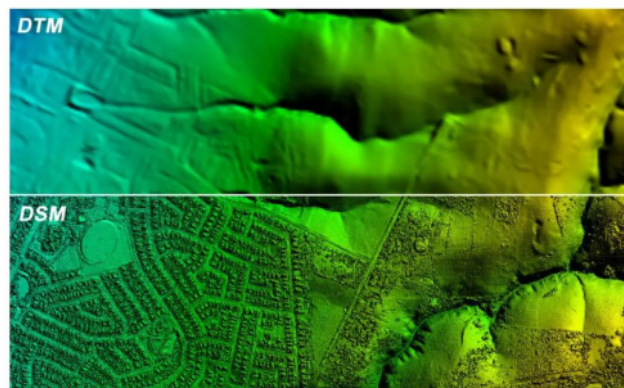


Figure 7 – Typical visualisation of a DTM and DSM of the same survey area [7]

3.3. Using photogrammetry software, the full colour images can be merged, combined with information such as the orientation and altitude of the camera, additionally with the pixel

size and lens distortion, precise locations in 3D space can be deduced by the software's algorithms. [11]

4. Recommendations

- 4.1. From the information collated during this report, there are several different approaches that can be taken to acquire RS&I data. Before any information is gathered the required resolution is necessary to make an appropriate selection.
- 4.2. As discussed previously in the relevant sections of this report, each method has its own benefits and limitations, although all methods require the storage and processing of large quantities of data depending on the level of detail, or resolution required.
- 4.3. To enable a survey of the required area to the specified resolution would be to use UAV equipped with LiDAR. Combining this platform with this scanner will give the best and most accurate visual representation of the survey area, with the ease of acquiring the data from a logistical point of view. Consideration of the data processing must be given, as with LiDAR scanning a substantial amount of data will be generated, therefore must be stored correctly.

Part 2B

1. Introduction

- 1.1. It was asked that an investigation be conducted into the suitability of remote sensing and imagery for use in locating and identifying land mines during or after conflict. 12 Inert Representative Land Mines (IRLM) were hidden in various locations at a waste ground near the University of Wales Trinty St. David (UWTSD), IQ Building, Swansea Marina.
- 1.2. Currently ongoing in the Ukraine conflict, drones with IR imaging are being used to identify land mines by passing over the survey area at very low altitudes at dusk. As the mines retain residual heat from the sun which is clearly discernible from the surrounding ground when viewed using Thermal Imagery (TI) at that specific time of day, this method and its practicality was assessed. Using the resources provided it was possible to locate and identify the hidden IRLMs efficiently and effectively.
- 1.3. The raw data gathered during the practical exercise has been collated and incorporated into QGIS software package for ease of visualisation. This brief report will explain the methods used to identify points of interest for review.

2. Layer Types

- 2.1. By using GQIS in combination with Ordinance Survey data, high resolution images of the marina area were obtained and input as a raster layer. This is shown on Image 1 within the visualisation PDF. These images give an initial indication of the area and its topography.
- 2.2. By adding a shapefile layer to the QGIS project, it was possible to use the draw polygon function to clearly identify the specific survey area. The blue lined area is the total area to be surveyed. In addition to showing the survey area, the large body of water was highlighted with red hatching. This area was unable to be surveyed by ground methods

(SPOT) due to the risk of damaging the platform but was still able to be surveyed aerially by drone.

- 2.3. When images of the IRLM were obtained these were also incorporated into the software. While locations settings are active on a smartphone camera the longitude and latitude of where the images were taken is recorded. When these images are added to the QGIS project the co-ordinates are automatically linked to the images, which are georeferenced to the appropriate location, this is shown in Image 3 of the visualisation PDF.
- 2.4. When topological data for the area was acquired from ordinance survey, specifically building heights, it highlighted that there are discrepancies between various data sets. Image 4 includes this data which clearly shows buildings present that are not included on the high resolution arial photometry.
- 2.5. Using LiDAR data available from ordinance survey a Digital Surface Model (DSM) and Digital Terrain Model (DTM) layers were produce and added to the QGIS project, this is shown in Image 5 and 6 respectively. A DSM shows the area as seen from above which includes all vegetation and buildings. While a DTM displays the terrain itself with vegetation and buildings removed to allow a clear view of ground contours.

3. Accuracy of Data

- 3.1. Each of the layers discussed in Section 2 have their own specific method of acquiring the data, each of these methods will have its own limitations and error associated with the data. Powerful computing allows the data to be validated and compiled into a visual representation, although all data will naturally have errors when collected, when processed and when verified.
- 3.2. Scaling factors, repeatability of results and the resolution of each of the datasets used are critical to ensure accurate data visualisation. Additionally each platform used will induce error within the data that needs to be accounted for and amended correctly.
- 3.3. Interpretation of the data is critical to ensure that the correct attributes are selected and valuable date is acquired in the first place. In addition to the selection of appropriate data, the time of which that data was acquired is crucial its accuracy. Data is only relevant for that instance in time it was gathered. This is shown in the visualisation PDF, specifically the presence of buildings on some datasets and not others, this shows that if confidence is needed in the result, multiple methods of RS&I data acquisition should be used in addition to physical visits to the survey area.
- 3.4. The purpose of this practical was to use TI to identify IRLM, the outcome of the survey showed that further work is needed on the practical scenario. As the IRLM were not buried as initially intended this reduced the amount of heat retained by the IRLM, in was expected that they would be clearly discernible to the surrounding ground. This was not the case, the IRLM appeared as block bodies, this was also believed to be from the emissivity of the IRLM case material.
- 3.5. Below, Figure 1 shows a side-by-side Thermal Image and high-resolution image of the survey area, the red circle identifies an IRLM. As seen in the image the IRLM was barely

visible with the TI camera as anticipated, under the conditions of this practical examination this method of identification was unsuitable in this application.

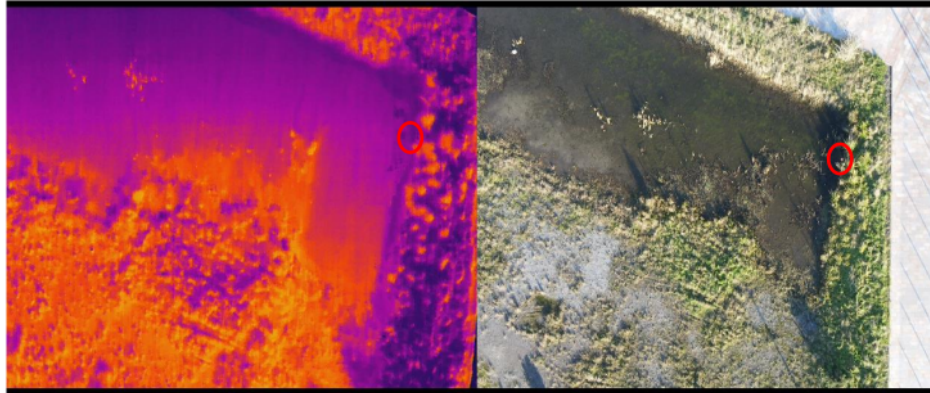


Figure 1 – Side by side Thermal Image & High-resolution Image – IRLM Circled

- 3.6. Future practical examinations should be conducted to allow the burying of the IRLM and for the survey to be conducted at sunset as was intended initially. This should allow for, as far as reasonably practical, real-world representation of the scenario which could then identify if TI by drone is a suitable method of identifying and locating IRLM.

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GRADEMARK REPORT

FINAL GRADE

68/100

GENERAL COMMENTS

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