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Analyze Imagery and Other Data Collected at the Los Alamos National Laboratory

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PII.2 Analyze Imagery and other Data Collected at the Los Alamos National Laboratory

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Introduction

Unfortunately, areas of waste disposal at DOE sites are not all documented and located. There are a number of reasons for this situation: records have been lost or destroyed, the locations were not documented, and memories have been lost. The search of large areas at these sites for buried waste and buried-waste containers is a difficult and expensive problem when using conventional, ground-based methods. Typical conventional methods involve the drilling of wells/boreholes (point sampling), and interpolation is required to obtain the needed areal information.

Drilling for buried waste is expensive, potentially hazardous, and time-consuming, yet accurate interpolation can require a large number of holes per-unit-area. A similar problem is encountered in gaining current information about: the boundaries of toxic waste plumes in the ground, transport pathways, and the composition and concentration of toxic materials.

The purpose of this effort is to analyze existing imagery data collected under various Department of Energy and other programs. This analyses will be useful for screening, characterization, and monitoring work in the waste site remediation process.

Objectives

With drilling operations costing hundreds of thousands of dollars per hole, the reduction in the number of holes is of great concern. And just as importantly, safety must be a principal consideration when drilling to explore for unknown buried waste. Alternatives to conventional ground-based methods need to be evaluated. To consider alternatives an effort was begun to analyze existing remotely sensed data. By using remote sensing methods to reduce the ground area to be considered, the amount of actual drilling needed can be reduced.

The Los Alamos National Laboratory (LANL) is the initial test facility for the

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collection of remote sensing data from aircraft and satellite. The remote sensing data includes optical, multispectral, infrared and radar. This technique will survey large areas for underground structures (i.e. pipe lines, buried objects) and disturbed areas which provide information on contaminants and trench locations. The Environmental Research Institute of Michigan (ERIM) was contracted to collect the data, choose sites of focus and perform special processing developed from defense and intelligence applications. The results have been presented to on-site managers for determining the site specific applications.

Approach

Remote sensing is a technology that is well suited to the surveillance of large areas for detecting and locating buried objects, mapping seepage from buried containers and detecting the boundaries of toxic plumes. Remote sensing provides spatially continuous information to achieve the accurate interpolation of point sampled data.

Image processing and data integration algorithms have been developed and validated under funding by defense and intelligence organizations. They have been applied to the detection of buried objects, vegetation stress, soil moisture and liquid migration, and change detection. The algorithms are based upon phenomenology that is also relevant to the detection, mapping, and monitoring of waste materials. ERIM has integrated these algorithms into a methodology that was applied to waste detection and characterization at DOE sites.

New analysis techniques did not need to be developed and tested to solve DOE waste problems. Many of the chosen sites had archival data available for analysis which include aerial photography, multispectral and infrared imagery, radar imagery, and nuclear radiometry. Those data have been collected by commercial and Government sensors, and span an appreciable time interval. The specific tasks are:

Site Selection and Data Collection: Choose test sites at LANL based on the applicability of remote sensing and availability of prior characterization data at a site. Collect existing imagery and other data for processing and interpretation.

Organization of Technical Workshops: Organize two technical workshops; one to identify problems for study focus and understand the needs from the user's point of view; and a second to review the results with the various technical personnel of the LANL weapon complex sites.

Data Processing and Interpretation: Perform processing of data using the techniques developed for defense and intelligence applications. Based on the results, produce demonstration materials--a brochure detailing the data collection schemes and processing techniques. Integrate the processing techniques with Environmental Restoration Program at LANL, and design a collection scheme for future use at the DOE sites.

Project Description

Status: The Environmental Research Institute of Michigan collected imagery and other data, chose sites of focus and performed special processing. Algorithms were applied to the detection of buried objects, vegetation stress, soil moisture, liquid migration, and change detection, mapping, and monitoring of waste materials.

Potential sites at LANL were chosen as important areas in need of help from remote sensing. Existing imagery from each area was reviewed and site managers collaborated on the concept for solutions. Preliminary processing of imagery was done for many site problems and the most fruitful are being produced in a brochure.

Data Available: Imagery data useful for this project include airborne multispectral Daedalus imagery collected over Los Alamos by EG&G/EM in 1994 and coincident natural color aerial photography; LANDSAT TM, SPOT and 1989 Russian KFA-100 satellite imagery; historical photographs since 1935, ground photos taken during the project and recent orthophotos. Other information includes airborne nuclear (gamma) surveys flown by EG&G/EM in 1994, digital map information, and engineering drawings of burial sites.

Site Selection Criteria: About 10 sites were sought so that at least 3 or 4 would produce useful results. The first technical workshop was held in Los Alamos to invite Los Alamos site managers to suggest and review potential sites. To be a candidate, a site had to satisfy 5 criteria:

1.) The Los Alamos Environmental Restoration Program feels that some problem needs to be solved at the site.

2.) Some problem at the site is amenable to a remote sensing solution, that is, image phenomenology is scientifically possible.

3.) A site manager will take an interest in the project, that is, will take the time and has the knowledge to help find a solution.

4.) Good ground truth is available so that the demonstration products are credible.

5.) Imagery at the right times, wavelengths, resolution, etc., is already available.

Sites Selected: Ten sites were selected at the workshop:

Rofer Site: Detecting and delineating relatively known and unknown trenches.

Mynard Site: Determining location and extent of seepage for septic drain fields and holes, buried cable and firing pits.

Becker Site: Displaying sampling areas by hydrologic category and contaminant concentration.

Glatzmeier Site: Assessing a linear array of circles marked by vegetative damage.

Rofer-2 Site: Detecting buried tubes remaining from hydrologic tests.

Koch Site: Evaluating faults and fractures beneath waste disposal areas, assessing vegetative and thermal anomalies.

Hoard Site: Locating pits and comparing to engineering drawings.

Mason Site: Assessing thermal hot spots in an asphalt cap; locating contaminated trenches, shafts and drains.

Whole Lab: Relating gamma radiation contours to known contaminated areas.

Wheat Site: Locating two old landfills, one known, one unknown.

After the workshop, 3 sites were eliminated.

The Glatzmeier Site problem was resolved right after the workshop and was not considered an important enough application. At the Rofer-2 Site, ground disruption by recent environmental work severely degraded possibilities for a demonstration area. At the Wheat site only the low resolution lab-wide coverage was available so existing imagery was inadequate to address the problem.

Analysis Methods: Most of the actual image processing for the paper concentrated on the Daedalus multispectral imagery. Since this imagery is not as intuitive as simple photographs, the image pre-processing of bands is described below. Once some basic softcopy multispectral images were constructed, a visual procedure was started, analyzing these images along with SPOT, Russian and Landsat satellite images, historical and concurrent aerial photographs, site maps and other ground truth. The phenomenology of the signature of the particular waste site problem guides the special processing of an image. Successful approaches for known trenches and objects are applied to those that are not known. Often no additional image processing or image analysis was needed on any one image, but information from more than one image or map needed to be fused to aid the site managers in assessing a problem. This is especially useful at waste sites when there are conflicting information sources concerning buried waste locations. Data fusion is also discussed below.

Multispectral Image Pre-processing: DOE conducts periodic flights over the waste site areas with aircraft operating the Daedalus AADS 1268 Multispectral Scanner and a 70mm aerial framing camera. These data are collected, analyzed and archived by EG&G/EM. The EG&G/EM data base permitted retrieval of flight logs and imagery of the flight lines covering the pre-selected sites.

A set of flight lines were selected from the collection on 24 June 1994. These included both daytime and pre-dawn collections. The daytime imagery contained eight bands. The nighttime imagery contained only thermal bands (high and low gain channels). Flight lines were collected at an altitude of 1-1.5 km AGL yielding a ground resolution of 2.5-3.75 meters and at 5.5 km providing approximately 14 meter resolution.

The AADS 1268 is capable of recording data in up to 12 spectral bands. The following bands (corresponding to Landsat TM bands) were archived and used for this project:

Daytime Multi-spectral Imagery:

Band 1	0.45-0.52	TM-1
Band 2	0.52-0.60	TM-2
Band 3	0.63-0.69	TM-3
Band 4	0.76-0.90	TM-4
Band 5	1.55-1.85	TM-5
Band 6	2.08-2.35	TM-7
Band 7	8.5-12.5 (low gain 0.5)	TM-6
Band 8	8.5-12.5 (high gain 1.0)	TM-6

Predawn Thermal Imagery (long wave thermal band only):

Band 1	8.5-12.5 (low gain 1.0)	TM-6
Band 2	8.5-12.5 (high gain 2.0)	TM-6

Natural color aerial photography was also collected coincident with all flight lines. This provided very high resolution (estimated at 8-12 inches) with sufficient overlap to permit stereo analysis.

The Daedalus imagery was retrieved off of 8mm exabyte tape using both ERIM software (ERIPS) and commercial software (ENVI/IDL). The sites of interest were identified on the flight lines in softcopy and smaller images of the individual sites were taken from the flight lines. This was done to ease the analysis by reducing the amount of data.

Preliminary Visual Image Analysis for Detection Problems: Imagery was examined for signatures indicating the locations of trenches, other buried objects and contamination problems. The features were identified via site maps provided by Los Alamos. It is expected that detectability is driven by a variety of phenomena, including soil moisture, soil compaction, soil type, and vegetation type and vigor. Therefore, the first analysis step was a preliminary review of all data, with emphasis on daytime and nighttime thermal and reflective multispectral. The preliminary analysis was visual, using single images, multiple images in a side-by-side presentation, and multi-band or multi-image composites where appropriate (and where the quality of the registration permits). Data transformations such a Tasselled Cap and Principle Components were applied to the multispectral data and day/night thermal data was evaluated for thermal inertia effects. Visual aids such as histograms and scatterplots were also used. Following the preliminary analysis a more detailed analysis was done to better understand the conditions under which the signatures can be detected and to enhance detectability where possible.

Phenomenology: Generally there were three classes of issues;

1.) Locating buried objects or trenches,
2.) Detecting seepage from buried objects, pits or drain fields and
3.) Detecting faults and fractures.

These issues were linked to a set of observables.

Buried objects or trenches usually involve a significant disturbance of the soil which can have a long lasting and often visible effect in the surface. The process of digging up and replacing a large volume of soil creates differences in soil compaction and composition of the disturbed area in contrast to the surrounding undisturbed soil. These differences may result in different drainage over the effected area. Drainage differences result in soil moisture differences which, in turn, may result in vegetation differences (either vigor or type) and thermal differences due to differential evaporative cooling of the surface. In addition, trenches may cause subtle features on the surface either as subsidence due to settling or decay of the buried material or it may leave a mound where excess material is piled on top of the trench.

Seepage from buried objects, pits or drain fields results in soils moisture and nutrient differences which, in turn, may result in vegetation differences (either vigor or type) and thermal differences due to differential evaporative cooling of the surface. This is particularly a problem when the area has an asphalt cap and thermal differences from cracked spots indicate a possible problem.

Faults and fractures also result in soil type and soil moisture differences which may be directly or indirectly observed by assessing vegetative differences. Changes in surface temperature due to differences in soil moisture can often be observed in thermal imagery. If the surface is not directly visible due to vegetative cover, the age type and relative vigor of vegetation can sometimes indicate the location of faults and fractures.

Special Processing:

Burial Site Analysis: Burial sites were searched for evidence of soil or surface disturbances using a side by site comparison of the following band combinations:

(Bands 4,3,2) False Color Composite (looking for vegetation differences)

(Bands 6,4,2) SWIR Composite (looking for soil moisture and vegetation differences)

(Bands 7,6,2) Thermal Composite (looking for thermal anomalies)

(Band 7 or 8) Individual Thermal Bands (looking for warm and cool thermal anomalies and log stretch which has the effect of stretching the lower valued pixels in the image).

A principal components image was computed for trenches. A three color image of the first three principle components was evaluated for clumps of pixels with unusually large variances. Also, a Tasseled Cap Transform, a special case of principal components, was used to produce estimates of "greenness" and "wetness". The Tasseled Cap Transform is an established process for analysis of Landsat Thematic Mapper imagery. One of the outputs of the Tasseled Cap is a "greenness" transform band which has long been used as an indicator of vegetation vigor and "wetness" which is used as an indicator of vegetative moisture.

A comparison of the daytime and nighttime imagery was conducted to evaluate various areas showing unusual thermal inertia and vegetation stress. The comparison can by made by registering night image to daytime image, using side by side analysis, or using change or difference images.

Stereo analysis of aerial photography has been performed using the conventional mirror stereo scope. Some mounds and evidence of subsidence is visible but difficult to assess due to the vegetation cover.

Analysis of Drain Fields: The drain fields are being evaluated for evidence of vegetation vigor or stress and soil moisture patterns using the same techniques as for buried trenches.

Fault and Fracture Area Analysis: To analyze fault and fracture areas, the multi-spectral images are registered to the geologic map, then examined for spectral features within the known fracture region. The remaining area is searched for similar features

The AADS 1268 data covers the same bands as TM. A modified Tasseled Cap Transform (accounting for the difference in band order) was performed to produce a "greenness" image. The "greenness" image was evaluated to locate areas of vegetation vigor and stress.

Healthy vegetation maintains a relatively uniform temperature (by evaporative cooling). Stressed vegetation often has difficulty regulating its temperature. Ideally one would like to measure the vegetation's temperature at the minimum and maximum solar load (predawn and mid afternoon). A thermal image of the difference in temperature between these two times of day can provide indications of areas of stressed vegetation. While predawn thermal data is available, the daytime imagery was collected mid-morning. Nevertheless severely stressed vegetation might still show a temperature difference. To do this the predawn thermal image is registered to the daytime thermal image, the predawn image is subtracted from the daytime image, and the result is evaluated for vegetated areas with large temperature differences. An overlay is produced registering the results to the geologic map.

Data Fusion to Aid Users: To

provide a physiographic representation to the site analysts, layers of information were georeferenced and added. A typical application is to use multiple sources to aid in confirming or denying positions of buried objects. Imagery available in digital form was directly entered as a layer. Maps, diagrams, drawings or photographs not available in digital form were digitized or scanned, depending on the material. Information from georeferenced data bases were added as other layers. Often the layers of information are overlaid on a background image for context and to integrate the geographical features. Four commercially available packages were used--TNT MIPS, ERDAS with ARCINFO and ENVI with ARCINFO. The choice depended the particular workstation being used and preference of the particular analyst.

Results

Status: The final brochure will cover the remote sensing products that were selected for presentation. Interim products that have been made include the following: delineation of trench and old septic field boundaries using photography, maps and imagery; analysis of thermal signatures in unusual geological strata, asphalt and buried pits; analysis of fault and fracture areas beneath contaminated areas; broad radiological (gamma) data contours overlaid on imagery, compared to site problems; comparison of existing engineering drawings of buried objects with imagery and; use of hydrologic data merged with imagery to aid in soil sampling strategies.

Examples:

Rofer Site: False color or natural color composite with an overlay of suspected trench locations compared to a black and white thermal image showing anomalies; compared to historical photos.

Mynard Site: False color or natural color composite with an overlay of septic drain fields, holes, buried cable and firing pits from diagrams.

Becker Site: Display of hydrologic areas in a watershed and contaminated concentration values used to guide future stratified sampling of uranium, lead and copper.

Koch Site: A multispectral image registered to a geologic map to show faults and fractures; a "greenness" transform image side-by-side with a thermal difference image to assess areas of vegetative stress or vigor.

Hoard Site: Overlay of a detailed engineering drawing of buried pits on a natural color aerial photograph suggesting inaccuracies in the existing information.

Mason Site: Use of pre-dawn data to point out unexplained thermal anomalies in an asphalt cap; demonstrating/denying questionable information about buried trenches and seeps with a multispectral image.

Whole Lab: Overlaying gamma radiation data contours on a SPOT image of the lab, comparing to sites selected for this project, presentation of a Russian KFA-100 image as a newly available data source.

Applications

Economy: Rather than (or in conjunction with) statistical methods, analysis of remotely sensed data will provide information on where waste is located and on where wells should be drilled in order to obtain definitive characterization of waste sites. This would reduce the expense of exploratory drilling and the necessity for fine-gridded sampling.

Accuracy: Remote sensing's capability to provide (relatively) continuous information would be used to extrapolate conditions between wells/boreholes. This would improve the accuracy of information derived from point-sampling, and also would provide better data for waste-flow models.

Safety: In many situations there are risks associated with inadvertently drilling into containers and in working in areas where hazardous waste has migrated to the surface. Such conditions may not be known beforehand. Remote sensing provides the capability to detect and map such hazardous areas prior to beginning clean-up and mitigation.

Future Activities

To demonstrate remote sensing use as a tool for the surveillance of waste disposal at DOE sites requires a three phase process. This project represents Phase I which involves developing examples, by using existing imagery, of how remote sensing products could aid DOE's site restoration efforts. Phase II would optimize the results of the first year by collecting new data. Phase III would develop products at LANL in an operational DOE lab environment and transfer technology to the site restoration people.

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