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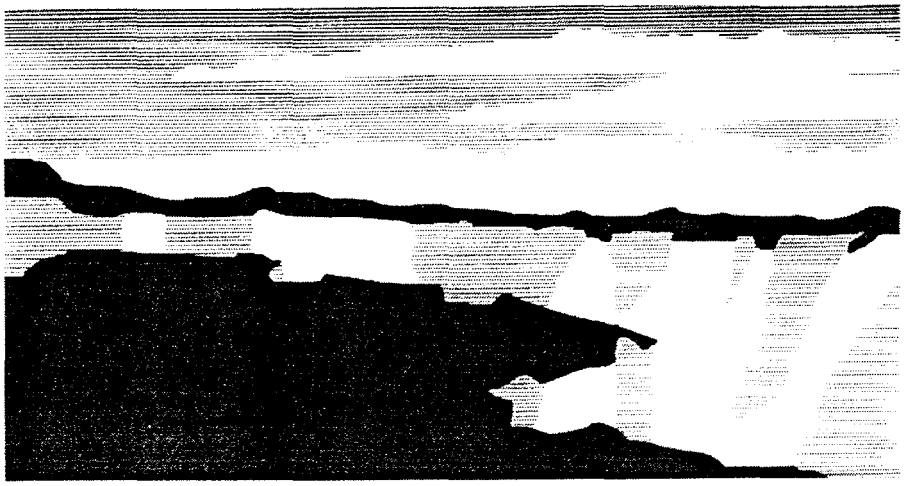

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Image Processing Technology

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Abstract

This is the final report of a two-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The primary objective of this project was to advance image processing and visualization technologies for environmental characterization. This was effected by developing and implementing analyses of remote sensing data from satellite and airborne platforms, and demonstrating their effectiveness in visualization of environmental problems. Many sources of information were integrated as appropriate using geographic information systems.

1. Background and Research Objectives

While the Laboratory has been developing noninvasive methods for characterizing waste sites based upon geophysical techniques, image processing and visualization methods have not generally been included. Image processing has been utilized for similar purposes elsewhere, but it has not seen much utilization at many DOE sites. Indeed, it is a major gap in site characterization and is beginning to be so recognized. There has been a fair amount of imagery compared on a visual basis, but little on a rigorous digitized basis. This project sought to do that comparison, demonstrate its utilization, and bring the needed added value from classified imagery to the problem.

Image processing is useful for those having to perform and monitor long-term environmental restoration activities: the DOE, DoD, EPA, and municipalities, to name a few. It also can be very useful in the international arena (e.g., Russia, air pollution, Mexico, NAFTA implications). The types of data being gathered run the gamut from historical aerial photography to more recent optical, radar, multispectral, and thermal infrared aerial and satellite imagery, both classified and unclassified. This data is being integrated with maps, geophysical measurements, chemical and radiological information, and site records. We are observing changes in soil disturbances, texture, and vegetation stress, among other changes. To

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manipulate and integrate the data, a geographic information system is being used, which provides efficient handling of various forms of data and allows spatial analysis of information layers.

The objective of this project was to prove the feasibility and test the accuracy of image analysis in providing information for specific environmental remediation (ER) targets. Three targets at Los Alamos were chosen: one dealing with locating old sumps (GMX-2); one to demonstrate overlaying various types of data onto historical photos (MDA-F); and another dealing with visualizing an environmental site in three-dimensions (TA-49). Eglin Air Force Base and a landfill site near Las Cruces, NM, were chosen as the DoD and municipality sites.

2. Importance to LANL's Science and Technology Base and National R&D Needs

This project supports Los Alamos core competencies in earth and environmental systems as well as analysis and assessment. The activities can help Los Alamos to intensify the focus on specific environmental issues facing DOE, DoD, and industry facilities and implement better technologies for environmental restoration and waste management across the DoD Complex.

3. Scientific Approach and Results to Date

The intent of this work was to evaluate how various visualization software packages could be utilized to characterize environmental problems. Two-dimensional visualization was accomplished using the software packages TNTmips, Photoshop, Illustrator, Motifshow, and others on Sun workstations, IBM PCs, and Macintoshes. Multiple examples of this follow. Three-dimensional visualization was accomplished by utilizing software packages such as Explorer and Open Inventor on the Silicon Graphics machine and SpyGlass Dicer on the Macintosh. These packages were not as straightforward or full-featured as the two-dimensional ones -- we had to write some of our own code for these. One specific example of this follows as well.

Besides attempting to evaluate and demonstrate visualization software, this project was utilized to gather resources that were needed as input to the characterization process. Thus we have obtained various types of images for Los Alamos and Eglin Air Force Base (classified US, Russian, Daedalus and radiation overflight data, and others.) A search of the national archives in Washington resulted in some unknown photographs of Los Alamos being discovered.

Los Alamos: GMX-2

One facility at Los Alamos that provided a good test site was the GMX-2 area. This site was used in the early 1950s for processing various hazardous materials, and was decommissioned by burning the buildings and removing the sumps. The sumps are of particular concern today, and need to be located accurately so that a field soil-sampling survey can be conducted. This site was chosen for this project since the sump locations are better known here than in other areas of interest. This proof-of-concept work consisted of two steps that were performed on digitized subsections of a 1965 aerial photo enlargement and 1991 orthophotos. Figure 1 shows a photograph of one of the sump areas after surveying in a "best" and "worst" location sump located from image processing. The "worst" is approximately four feet from the sump center, and is positioned outside of the sump depression. The "best" is approximately two feet from the sump center and lies within the sump depression. Both of these positions are consistent with the location errors derived from the image analysis, which is described in detail by Pope (June 1994).

Los Alamos: MDA-F

Another area at Los Alamos that has provided a good test site for analysis is Material Disposal Area F (MDA-F). A series of surveys were utilized to ascertain historical trench boundaries (and contents). Figure 2 shows an overlay of a magnetic survey on a 1958 historical photograph of the area. This visualization has led to further questions that are being evaluated as part of other studies (Pope, Aug 1994).

Los Alamos: TA-49

A third visualization example at Los Alamos was Technical Area 49. This area has detailed surface and underground features (shafts, drill holes, chambers, geology) that make it very interesting to visualize in three dimensions. One of the first steps we pursued was to write code within the Explorer and Open Inventor framework on the SGI. The problem was not so easy however (Whiteson, Aug 1995), and is not fully implemented at this time. Figure 3 shows one step in that process.

Eglin Air Force Base

Historical aerial photography was utilized at Eglin Air Force Base, Florida, to characterize Test Area C-46C. In the early 1990s, subsequent to the construction of a new advanced warhead experimentation complex, a radiological survey was conducted around this site that indicated higher-than-background radiation levels. It was believed that this radiation resulted from residual depleted uranium used in ordnance testing during the 1970s and the early 1980s. The goal of our effort was to: (1) locate and characterize likely sources for depleted uranium contamination, such as earlier target locations and (2) show the spatial relationship of these source areas to the test facility.

The historical imagery provided relatively precise location and characterization of objects that existed at the site during the 1970s and early 1980s. The tentative conclusions of this analysis indicate that the area was a staging area for nearby range facilities. Consequently, any depleted uranium contamination resulted from secondary sources, such as rain wash down of targets brought back to the staging area from a firing range. There is an additional possibility of residual contamination from ground based experiments, such as from flatbed mounted Gatling guns (Van Eeckhout, *et al.*, 1995).

Las Cruces: Municipal Landfill

The objective of this effort was to create a three-dimensional database with respect to a closed municipal landfill located southwest of Las Cruces near the Rio Grande River. This landfill appears not to meet current EPA and State of New Mexico criteria for site closure. Since the site is in close proximity to the Rio Grande and only a short elevation above the local water table, it will be characterized for potential site remediation, using historical aerial imagery and other map-based information.

Aerial imagery, providing a good record of pre-landfill, active landfill, and post-landfill site conditions, has been collected for the following years: 1947, 1955, 1960, 1967, 1972, 1974, 1975, 1980, 1984, 1986, 1989, and 1994. This imagery includes black and white photography, color photography, infrared photography, and radar photography. Data is also available from local soil maps and hydrology maps.

References

Pope, P., "Quantitative Accuracy Assessment of Locating Sump Positions at GMX-2," memo to Brad Martin, EES-3-94-221 (June, 1994).

Pope, P., "Comparison of Results from the Digital Analysis of Historical Airphotos and INEL's Magnetic Survey of MDA-F," memo to Cheryl Rofer, EES-3-94-276 (August, 1994).

Van Eeckhout, E., Pope, P., Wells, R., Rofer, C., and B. Martin, "Waste Site Characterization Through Digital Analysis of Historical Aerial Photographs at Los Alamos National Laboratory and Eglin Air Force Base," Los Alamos LA-UR 95-1270 (May, 1995).

Whiteson, A., "Development of Software Visualization Tools for Three-Dimensional Environmental Data," memo to Ed Van Eeckhout, EES-3-95-241 (August, 1995).

Fig. 1. A recent low resolution aerial photo of a facility at Eglin Air Force Base overlaid with targets containing depleted uranium from earlier images.

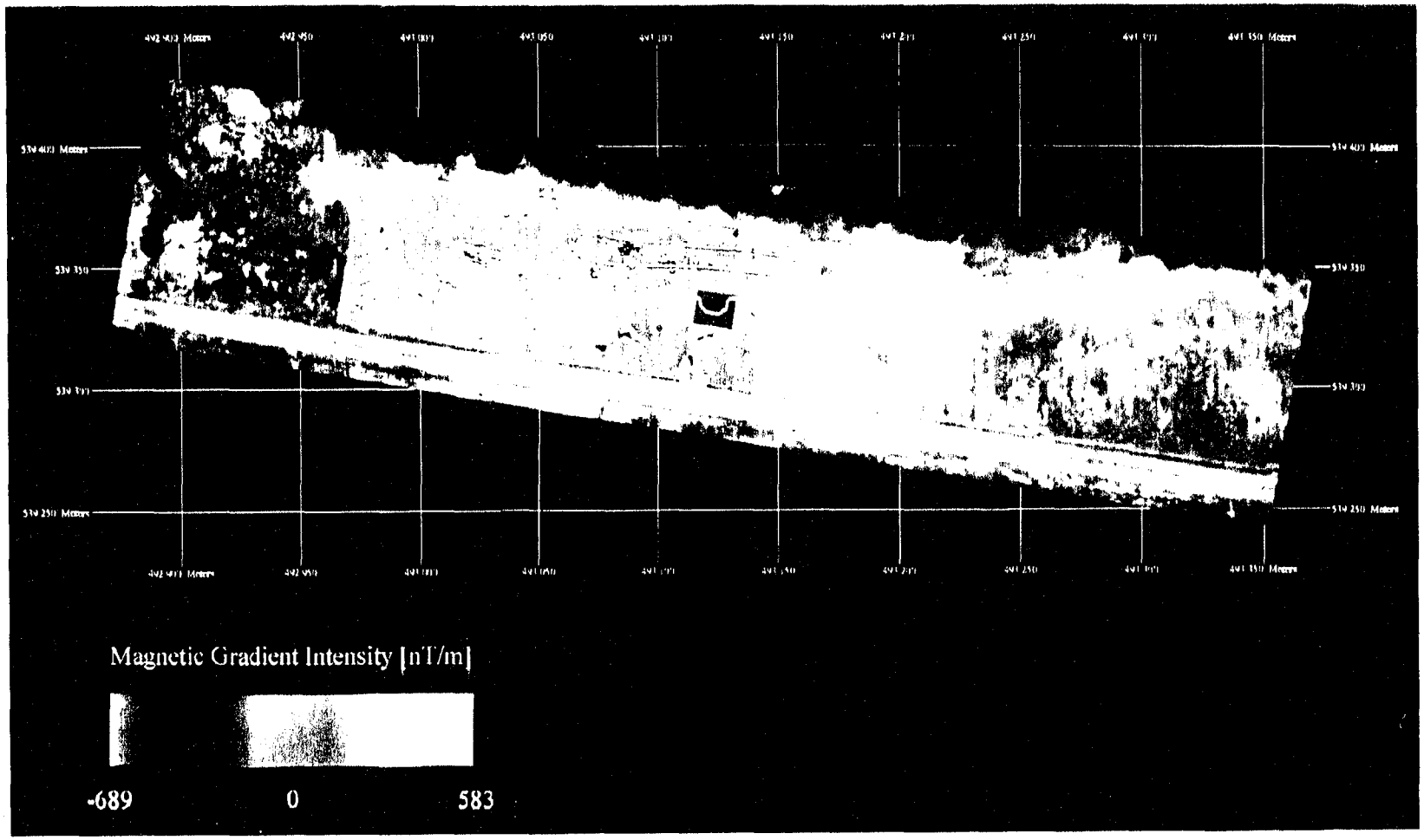

Fig. 2. A 1958 aerial photo of trenches at Los Alamos overlaid with data from a magnetic survey, suspected trench boundaries (magenta), the soil mound (yellow) boundary, and a NMCSP grid.

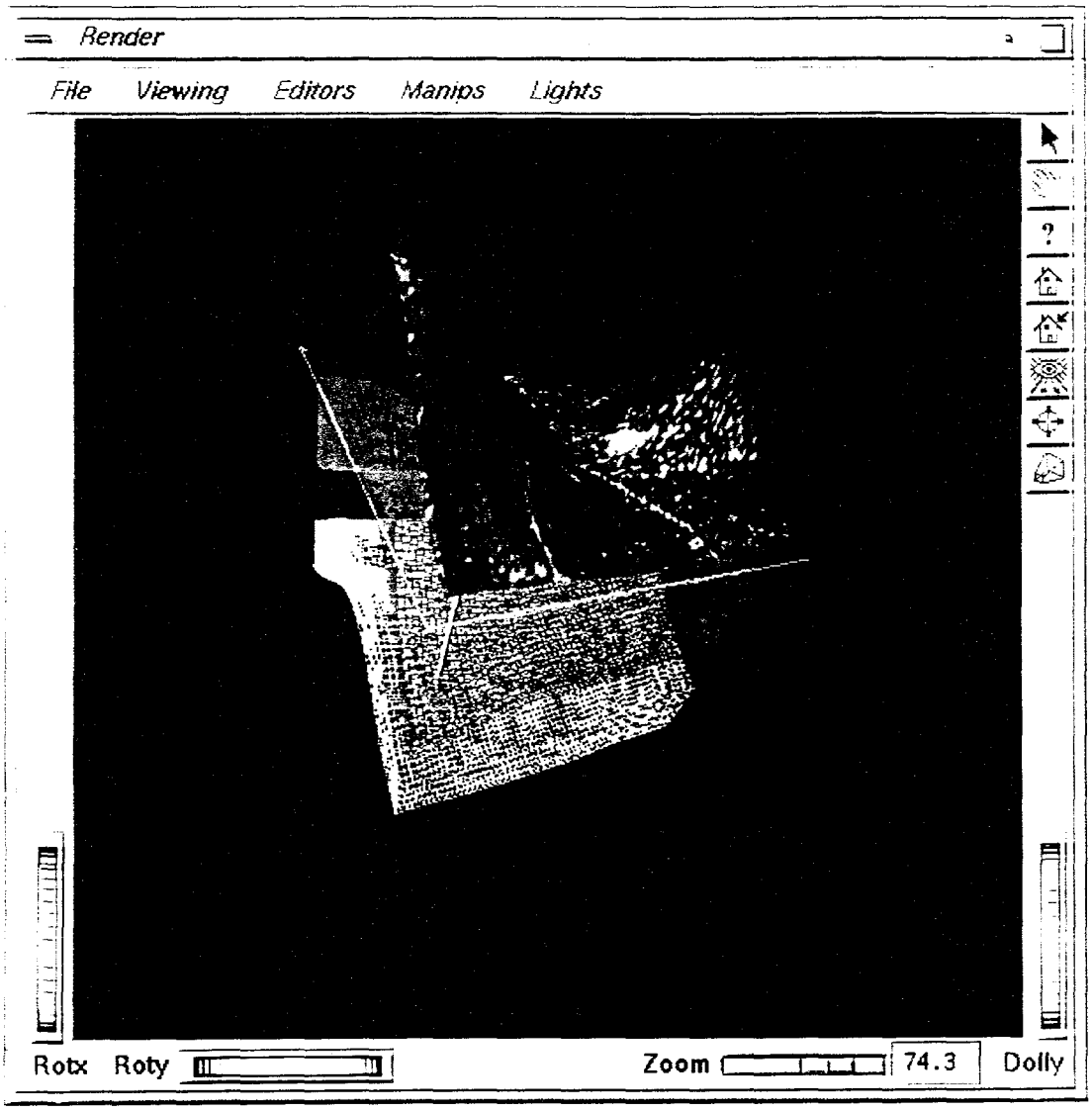

Fig. 3. A three dimensional view of surface and underground strata utilizing code written on the Silicon Graphics machine. Also visible in the nearest corner is a cylindrical structure representing a borehole.