SERDP Annual Report
CS1263

Project Title:
New Approaches to the Use and Integration Of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

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Project Background:
The Department of Defense administers 25 million acres of public land containing some of the nation's most significant historic and prehistoric cultural resources. Protecting these heritage resources is a fundamental part of the Department's primary mission. Heritage management issues central to that mission have focused on the economics of identifying and maintaining historic facilities, the impact of archaeological sites on construction and training programs, and the disposition and curation of artifacts. Cultural resources, defined in DoD Instruction 4715.3, include buildings, structures, sites, districts, and objects eligible for, or included in, the National Register of Historic Places regulation (36 CFR 60). Management of these resources, in compliance with existing laws and regulations such as *Native American Graves Protection and Repatriation Act* (25 USC §3001), the *Archaeological Resources Protection Act* (16 USC §470 aa-ll), *American Indian Religious Freedom Act* (42 USC §1996), and the standards in the *Curation of Federally-Owned and Administered Archaeological Collections* (36 CFR 79), necessitates the development of innovative and cost-effective methods for archaeological site identification, evaluation, and protection.

However, archaeological methods for the identification and evaluation of most historic resources remain essentially unchanged since the early twentieth century. Surface survey and excavation, the traditional field methods for discovery of artifacts, architectural elements, and other features, predominate in spite of the fact that these techniques are extremely time consuming, expensive, and unreliable. Their shortcomings manifest themselves in a variety of ways. Frequently there is no discernable surface evidence of significant buried archaeological features, making surveys ineffective. Excavation of small shovel-tests can be an effective way of finding sites but this entails substantial additional survey costs. In NRHP eligibility assessments, the ever -increasing labor costs restrict the number of test units that can be excavated, resulting in failure to locate features of significance. And more importantly, traditional invasive methods regularly lead to the damage or destruction of the very resources they were designed to investigate and generate costs associated with collection curation. Aware of these limitations, many archaeologists adopt a conservative, preservationist approach, with the result that DoD protects many sites of marginal scientific importance.

Methodologies for “seeing” into the ground and detecting subsurface archaeological deposits over large areas are needed. Various remote sensors are proving to be both useful and cost effective for this purpose. In the last 30 years a suite of space, aerial, and ground-based remote sensing technologies has emerged. It has been demonstrated that each sensor platform individually has great utility in identification and evaluation of cultural resources (Conyers 1998, Limp 1989, Hargrave 1999, Kvamme 1999, Kvamme 2001, Sever 1998). Integration of multi-scale, multi-platform, remotely-sensed data offers an opportunity to recover a great deal of information about archaeological site content while reducing costs associated with field work and long-term curation of excavated collections. Remote sensing includes a broad range of sensors that provide non-invasive measurements of the visible, thermal, magnetic, electromagnetic, and electrical properties of surface and subsurface properties of archaeological sites. Maps produced from sensors show the location of subsurface features, allowing us to reduce the amount of excavation needed to evaluate National Register eligibility. The detection of subsurface features lessens the risk of inadvertent discoveries of cultural resources and attendant mitigation costs. These techniques also provide a minimally invasive or non-invasive option for investigating potentially sensitive sites, such as those likely to contain human remains or those in areas that are designated Traditional Cultural Properties.

Objective:

The primary research contribution of this project lies in the exploration and assessment of the benefits of data fusion of a suite of ground, aerial, and space-based sensor data for the detection and identification of subsurface archaeological features. Large stacks of remotely sensed data sets are being acquired from up to six ground-based geophysical, two aerial, and one (of two) satellite sensor systems that will yield data at a variety of medium to high spatial resolutions (ranging from 0.01 to 1 meters). Historic and prehistoric sites at Fort Benning, Fort Bliss, Fort Riley, and a DoE property on the Savannah River have been chosen for data acquisition and field testing, based on their range of environments and archaeological resources. Existing multi-sensor data sets from two extensively surveyed civilian sites will also be incorporated into the study. These massive data sets will be processed using existing and newly developed data analysis and fusion methods in both two and three dimensions with a goal of making predictions about the specific nature of buried archaeological deposits. These geophysical and remote sensing predictions will be tested at the installations through a rigorous program of archaeological field examinations involving coring and excavations.

This research that will identify the specific combinations of remote sensors and data fusion techniques that are best suited for various environments and archaeological circumstances.

The goals of this research include:

- Application of a suite of established and newly fielded, high resolution, space and aerial instrumentation to the detection of cultural resources.
- Examination of a suite of existing and newly developed ground based instruments applied to the detection and evaluation of subsurface deposits.
- Application of existing and development of new computational approaches to the multi-scalar data fusion/analysis of an extensive suite of satellite, aerial, and ground-based remote sensing data sets.
- Assessment of the results of these approaches through a testing program in a range of environments and archaeological site types.
- Creation of a comprehensive within site/within method and between site/between method matrix of sensor combinations, site conditions, and fusion methods, and development of effective guidance documents for their use in different settings.

Due to the late start date of the project, goals for Year 1 include preliminary surveys to select specific sites at Forts Bliss, Fort Benning, and the Savannah River property, equipment purchase, initial geophysical data acquisition, and acquisition of existing data sets.

Technical Approach:
In this project we plan to apply the following sensor methods: (1) magnetometry, (2) magnetic susceptibility, (3) electrical resistivity/conductivity, (4) ground penetrating radar, (5) terrestrial and aircraft thermal infrared, and (6) satellite based, high resolution multispectral (visible, near-IR). We have learned that while a single sensor can provide great insight, expanded benefits may be realized through the integration of multi-sensor data. New fusion and classification methods effectively combine the net information content of multiple sensors, yielding a dramatic increase in our ability to recognize patterns and detect cultural features. New sensor systems and new computational approaches to multi-sensor data integration, fusion, and analysis have set the stage for the development of what we believe will be significant new capabilities.

The outcome of this research program will be a determination of methods that work well individually and collectively, and will result in the production of intrasite and intersite matrices of the sensor combinations, site characteristics, and archaeological characteristics. The research will demonstrate the nature of sensor similarities, differences, redundancies, and performance characteristics. It will describe the kinds of archaeological features that may be detected with each method or combination of methods under various environmental conditions. Finally the study will offer a cost-benefit analysis. An important aspect of the research will be an assessment of the added value of the fused product compared to traditional, individual sensor based analysis. A key part of the approach is to utilize COTS (commercial off-the-shelf) software solutions in an innovative manner and leverage existing DoD/DoE software developments, making it possible to quickly transfer the results and technology to a broad user base.

Project Accomplishments:

The University of Arkansas was officially authorized to begin this research project November 18, 2002. The limited number of activities conducted prior to that date was funded by a pre-award contract approved by SERDP.

Project Planning Meeting July 2002

The research team met in Manhattan, Kansas to discuss a variety of issues associated with the project including survey design, sample density, change detection, information validation, data analysis, testing, interpretation, and scheduling. Participants were Tom Sever and Burgess Howell (Marshal Space Flight Center/NASA), Mike Hargrave (Construction Engineering Research Labs/CoE), Lewis Somers and David Maki (GeoScan and Archaeo-Physics), Ken Kvamme, Debbie Harmon, Eileen Ernenwein and Fred Limp (University of Arkansas, Fayetteville).

Equipment Acquisition

The project purchased an Geonics, Ltd. EM38B Ground Conductivity Meter and a Palm IR 250 Thermal Imager in calendar 2002.

Site Surveys

Due to the late date for project award, field investigations have not all been completed at the writing of this report. Team member initated site surveys at Army City, Fort Riley, Kansas. July 2002; the Silver Bluff Plantation, Savannah River, South Carolina, November 2002; and Kasita Town, Fort Benning, Georgia, November 2002. The surveys acquired ground geophysical data only. All geophysical survey was completed at Fort Riley in July 2002. The radar component of the geophysical surveys is underway at Benning and Savannah River as this report is being prepared. Comprehensive geophysical survey at Fort Bliss is anticipated for May/June 2003. Other data acquisitions are scheduled for 2003 following development of appropriate field conditions for the thermal and satellite data acquisitions. Mike Hargrave conducted coordination with all installation staff and each was fully briefed on the project, its goals, and operations. Details on field investigations are provided below.

Acquisition of Legacy Data

Mount Comfort Church, Arkansas, Geophysical Survey 2000-2001

Mount Comfort Church is a 255 sq meter historic site in Washington County, Arkansas located on a creek terrace in Ozark Mountain foothills. The site dates between 1840-1863. The geophysical data collected in the 2000 and 2001 field seasons were acquired for this project. The following summarizes the site and surveys.

Site Description

The Mount Comfort Church was constructed of brick in the 1840s. The Confederate newspaper *The War Bulletin* describes the Confederate Mount Comfort Hospital and the deaths of 12 men in January 1862. It likely served as one of the 14 field hospitals used by the Union after the Battle of Prairie Grove in December 1862. One such building is noted as "the brick church," but unfortunately we don't know whether or not this is the Mount Comfort Church. We do know the building burned. Oral history relates that bricks from the building were salvaged by Union troops to build barracks in Fayetteville, probably in 1863 or 1864 when the town was being fortified. Test excavations by Jerry Hilliard of the Arkansas Archeological Survey revealed brick walls less than 35 cm deep, thousands of machine cut nails, all burned, and stove parts.

Geophysical surveys were conducted at the church from 2000-2001 in a collaborative effort by the University of Arkansas (including students enrolled in a "Near Surface Prospection" class), and the Arkansas Archeological Survey. Magnetic gradiometry, electrical resistivity, and ground-penetrating radar techniques have all been used to successfully detect the buried foundation.

Magnetic Gradiometry Survey

Instrument: Geoscan Research FM-36 fluxgate gradiometer; Sampling Interval: 0.5 x 0.125 m; Prospecting Depth: up to 1.5 m; Area Surveyed: 400 sq m; Date of Survey: Feb-2001; Land Cover Type: Mowed Grass.

The basic shape of the structure was seen in the magnetic data, probably due to the higher magnetic susceptibility of remnant bricks.

Electrical Resistivity/Resistance Survey

Instrument: Geoscan Research RM-15; Sampling Interval: 0.5 x 0.5 m; Prospecting Depth: 0.5 m; Area Surveyed: 1,200 sq m; Date of Survey: 2000-2001; Land Cover Type: Mowed Grass.

Electrical resistivity survey area revealed the foundation of the historic church in the upper right area as well as a number of roads, tracks, and other features; A detailed examination of the church area showed its outline and interior support piers, all probably of more resistant brick.

Ground-Penetrating Radar Survey

Instrument: Geophysical Survey Systems SIR-2000 with 400 MHz antenna; Sampling Interval: 0.5 x 0.02 m; Range: 40 nS; Prospecting Depth: About 1.5 m; Area Surveyed: 255 sq m; Date of Survey: Mar-2001; Land Cover Type: Mowed Grass.

Thirty GPR profiles, each 0.5 m apart, were subjected to time slicing to produce plan graphics; Close inspection of the data revealed clear evidence of the church foundation in the 8-16 nS time slice, with evidence of perhaps a walkway seen in the 0-8 nS time slice.

Whistling Elk Village (39HU242), South Dakota Geophysical Survey 1998-1999

Whistling Elk is a large (170 x 110m), fortified, Initial Coalescent village of the Plains Village pattern in Hughes County, SD dating to the early AD 1300s. It is located on the north bank of the Missouri River about 30 km east of Pierre, South Dakota and is on a loess plain/river terrace. The 1.8 ha site is owned by the U.S. Army Corps of Engineers. It is buried under nearly a meter of sediments with no surface expression of cultural features visible aside from vegetation markings that occasionally appear in aerial photographs. Most of the village area was designated a natural wildlife refuge in the 1960s by the Army Corps of Engineers (CoE) when this section of the river was impounded to form Lake Sharpe, one of the many reservoirs on the Missouri. The lake's erosion of the site has recently resulted in a CoE bank stabilization program along its shoreline.

Little is known about Whistling Elk aside from excavations of two prehistoric houses performed at the eroding embankment by the University of Nebraska at Lincoln during the late 1970s. These excavations showed that the houses were burned, probably during an attack because the floors contained numerous utilitarian artifacts and burned foodstuffs (maize, beans) in storage bins. The excavations reported a depth to cultural features at the cut-bank of 0.8-1 m. Radiocarbon dates clustered in the early AD 1300s.

The results of the electrical resistivity survey covered an area of approximately 17,000 sq m. Cultural features, nearly a meter deep, tend to exhibit high resistivity due to differing electrical properties of the eolian sediments that in-filled house and fortification depressions after the site's abandonment. The electromagnetic conductivity survey covered an area of approximately 16,600 sq m. The theoretical inverse of resistivity, cultural features exhibited low conductivity. The magnetic gradiometry survey covered an area of approximately 16,200 sq m. Cultural features tend to exhibit higher magnetic responses due to the presence of hearths and burned features like houses. The northwest quadrant of this village was not surveyed by conductivity or magnetic methods owing to the presence of a steel wire and post fence.

A particularly exciting find was the discovery of a "Big House," an unusually large house (10 m wide) possibly used for ceremonial purposes. The geophysics revealed its square form, exterior entryway facing southeast, the central hearth, and at least three of the central support posts, all classic features of Initial Coalescent houses. The magnetic data also indicated extensive burning along its walls. The University of North Dakota archaeological field school, directed by Dennis Toom, performed test excavations in the Big House. These excavations confirmed the locus of the hearth, a major support post, and the presence of intensive burning. The floor contained bison bone and numerous artifacts, including a complete pot. Depth to the floor was 98 cm.

The resistivity data clearly define numerous houses and the fortification ditches, including nine bastion loops. The conductivity data are less clear, possibly owing to peak sensitivity near a depth of 40 cm, somewhat above the cultural features. One consequence is that historic plow marks, above the cultural levels, are readily apparent and illustrate two distinct fields (one plowed east-west and the other north-south). Several houses not clearly defined by the resistivity data are better revealed by conductivity methods. The magnetic information, while appearing very noisy at a global scale due to historic iron debris and a plow mark response, offer a wealth of information at larger scales. Portions of a burned palisade are discernable as well as interior house features like hearths and post holes, as illustrated in the "Big House." In all of the data sets the berm constructed by the CoE for bank stabilization is readily apparent, and the steel wire and post fence impacts all of the data sets due to the sensitivity to ferrous metals of magnetic and conductivity methods and a vegetation response measured by resistivity (a dense tangle of weeds near the fence probably lowered ground moisture thereby raising resistivity in this area). Some of the noise seen in the northwest quadrant of the resistivity and conductivity data is due to an unusually high density of rodent activity in this area. The somewhat washed-out response to the north of the fence line seen in the resistivity data is probably due to the fact that this field has been under continuous cultivation and, indeed, was under oats during our survey (we were allowed survey of this field after the oats were cut). An extra 30 years of continuous plowing and probably a different moisture regime may be responsible for the weaker signature seen.

The discovery and definition of an inner fortification system with bastion loops and an increased density of houses within (partially due to the superpositioning of later houses over earlier ones) supports the inference, made by the 1970s excavators, of an attack on this village. It is quite possible that Whistling Elk was reoccupied by survivors and consolidated into a tighter, more defensible settlement, a circumstance seen in other villages in the region.

We believe this project clearly demonstrates some of the benefits of archeogeophysical survey. The structure of a prehistoric settlement is clearly revealed offering a detailed, and probably unprecedented, look at the layout of an entire Initial Coalescent village. The form of fortifications, the spacing of bastion loops, and the arrangement of houses within are indicated. In some cases house form and even interior features are revealed. Of particular importance is the discovery of an inner village with its own fortification system that may suggest a reoccupation and consolidation of the village after an attack. The unusually large Big House was also revealed by the remote sensing methods that were able to pinpoint features with sufficient accuracy for excavators to place a trench exactly between its wall and the central hearth!

Electrical Resistivity/Resistance Survey

Instrument: Geoscan Research RM-15; Sampling Interval: 0.5 x 1 m; Prospecting Depth: 1 m; Area Surveyed: 17,000 sq m; Date of Survey: July 1998; Land Cover Type: Open mowed grass/weeds.

Electrical Resistivity Tomography Survey

Instrument: Geoscan Research RM-15 & MPX-15 Multiplexer; Sampling Interval: 0.5 x 0.5 m; Prospecting Depth: 0.5, 0.75, 1.0, 1.25, 1.5, 2.0 m; Area Surveyed: 200 sq m; Date of Survey: July 1999; Land Cover Type: Open mowed grass/weeds.

Electromagnetic Conductivity Survey

Instrument: Geonics, Ltd., EM-38; Sampling Interval: 0.5 x 1 m; Prospecting Depth: to 1.5 m; Area Surveyed: 16,600 sq m; Date of Survey: July 1998; Land Cover Type: Open mowed grass/weeds.

Magnetic Gradiometry Survey

Instrument: Geoscan Research FM-36; Sampling Interval: 0.25 x 1 m; Prospecting Depth: 1-1.5 m; Area Surveyed: 16,200 sq m; Date of Survey: July, 1998; Land Cover Type: Open mowed grass/weeds.

Ground Penetrating Radar Survey

Instrument: GSSI SIR-2000, with 400 MHz antenna; Sampling Interval: 0.02 x 0.5 m; Prospecting Depth: about 2 m; Area Surveyed: 75 sq m; Date of Survey: July, 1999; Land Cover Type: Open mowed grass/weeds.

Ten 15 m ground penetrating radar transects were run over a 5 m length of the fortification ditch at Whistling Elk Village, SD, each separated by 50 cm.

Army City (14RY3193), Fort Riley, Kansas Geophysical Survey 1996-1997

Army City is a historic site in Riley County, Kansas, owned by the U.S. Army. The AD 1917 military base is 92,400 square meters located on low rolling hills. Data from 1996-1997 surveys of this site, summarized below, were acquired for the current study.

Army City was a World War I era commercial complex established to provide entertainment and other services to troops at Camp Funston (now part of Fort Riley, KS). The town was created in 1917 and presently rests under a hay field with almost no indications on the surface of its presence.

In 1996 and 1997, resistivity, magnetometry, and limited ground penetrating radar surveys were conducted along with limited archaeological excavation to demonstrate the eligibility of the site for listing on the National Register of Historic Places. A total of 3,600 square meters was examined with resistivity and 5,600 square meters were inspected with magnetometry. The geophysical instruments used were both made by Geoscan (RM-15 and FM36, respectively). The geophysical data was used to guide limited testing efforts for maximum information retrieval. The geophysical surveys enhanced other data sources in the nomination of this site to the NRHP.

Magnetic Gradiometry Survey

Instrument: Geoscan Research FM-36; Sampling Interval: 1 x 1 m; Prospecting Depth: 1-1.5 m; Area Surveyed: 5,600 sq m; Date of Survey: 1996 and 1997; Land Cover Type: Prairie.

Electrical Resistivity/Resistance Survey

Instrument: Geoscan Research RM-15; Sampling Interval: 0.5 m x 1 m; Prospecting Depth: 0.5 m, 1 m; Area Surveyed: 3,600 sq m; Date of Survey: 1996 and 1997; Land Cover Type: Prairie.

Acquisition of Legacy Data Fort Bliss

Dr. Brent Ruby provided the research team with existing geospatial data for Fort Bliss. Data sets include panchromatic and color infrared photography, DRGs, DEMs, and a variety of shapefiles.

Geophysical Surveys 2002

Army City (14RY3193), Fort Riley, Kansas

During the summer of 2002 another round of data acquisition at Army City was completed with funding provided by SERDP. This report provides initial and very preliminary results obtained during that field season.

In 1995-96 most of the entire town was geophysically surveyed by Geoscan Research using electrical resistance methods, discussed above. Their results provided good indications of many features of the town as well as a paleo-channel to the northeast now invisible on the surface (see http://www.cast.uark.edu/nadag/projects_database/Somers1/Somers1.htm for additional details about this work). In 2002, 1.6 ha were surveyed. Data from five geophysical methods, most of which respond to different dimensions of subsurface physical properties, are presented below, with many similarities and differences apparent. An ultimate goal of the project will be to employ the data together, simultaneously, utilizing a variety of new data fusion approaches that ultimately will indicate better detail and new insights about this important site.

Thermal (palm 250IR), high resolution panchromatic and multispectral data from aerial (Duncan DI 4500) and space-based platforms (the QuickBird satellite) will soon be fused with the geophysical data to yield an even clearer understanding of the subsurface content and organization of Army City. Vegetation patterns indicated on the surface during fieldwork (see Resistivity, below) suggest great promise from aerial methods.

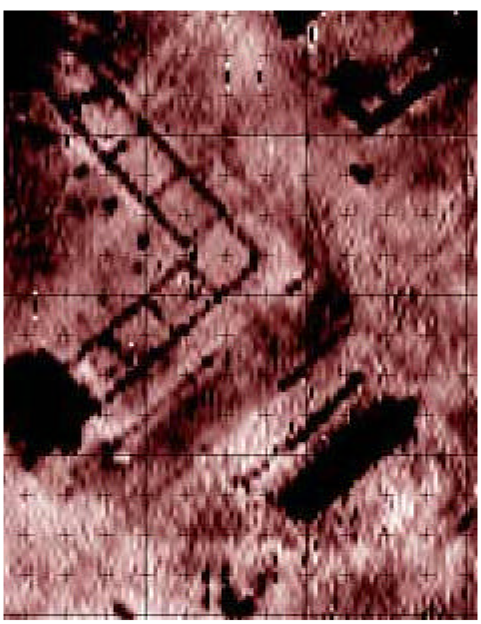
Site Mapping

A detailed mapping of all surface-visible features and indications of subsurface changes was undertaken throughout the study area. There was a wealth of evidence about the subsurface was detectable at the surface with the human eye. These data will ultimately be compared with the various forms of remote sensing evidence. GIS technology, together with new “data fusion” software, will ultimately allow thorough analysis, combination, and understanding of these data.

Resistivity Survey

Instrument: Geoscan Research RM-15 with MPX-15 multiplexer; Prospection depth: 0.5 m; Sampling interval: 0.5 x m; Area surveyed: 16,000 m2 (1.6 ha); Date of survey: 7/2002, Land Cover Type: Mowed Grass.

As shown in this portion of the total data, the resistance data clearly reveal individual walls and rooms of a large structure in the northwest, historically called the "Hippodrome." Some of these walls were visible as vegetation markings seen on the surface.



The principal northwest-southeast trending street, known as "Washington Street," is readily seen as are a number of other structures, including the "Orpheum Theater" in the north-central portion of the study block. Of large interest is the faint outline of a rectangular structure seen in the south-central portion of the study block that is indicated as a series of unconnected dots represent building footers. These features are revealed despite the somewhat coarse sampling interval employed (relative to the size of these features), indicating the robust contrast they offered compared to the background data. Surprisingly, these anomalies are also clearly indicated by vegetation marks in the surface. They can also be discerned in the G PR data but not in the other imagery.

Electromagnetic Conductivity Survey

Instrument: Geonics, Ltd. EM-38, quadrature phase; Prospection depth: 1.5 m, with peak sensitivity at 0.4 m; Sampling interval: 0.5 x 1.0 m; Area surveyed: 16,000 m2 (1.6 ha); Date of survey: 7/2002. Land Cover Type: Mowed Grass.

While soil resistivity and conductivity are the theoretical inverses of each other, the results of these surveys include important differences stemming from the very different instrumentation employed to obtain each data set and variations in the soil volumes evaluated. The raw conductivity data largely illustrate, at present, highly conductive buried pipes that lie beneath many of the buildings. Some building outlines are indicated, however, including a different visualization of the south-central rectangular structure. Initial processing of these data employed despiking to remove some of the low-level metallic noise, a high-pass filter for trend removal, and a low-pass filter for further noise suppression. A number of subtle details not apparent in the raw data are enhanced and it becomes possible to visualize features within saturated areas around the many pipes.

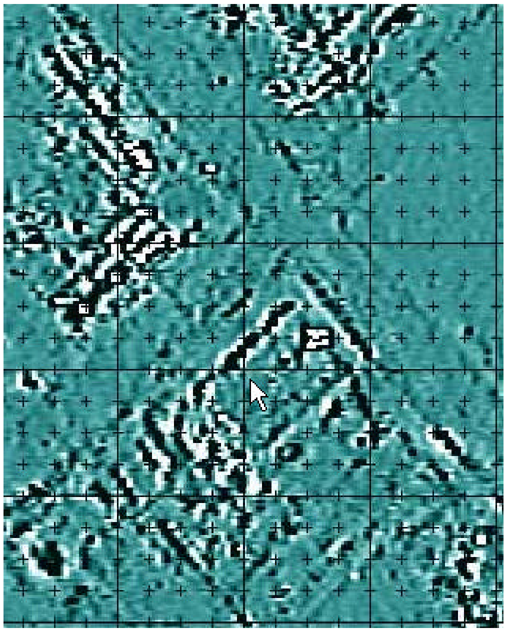
Magnetic Gradiometry Survey

Instrument: Geoscan Research FM-36 fluxgate gradiometer; Prospection depth: up to 1.5 m; Sampling interval: 0.25 x 1.0 m; Area surveyed: 16,000 m2 (1.6 ha); Date of survey: 7/2002. Land Cover Type: Mowed Grass.

The magnetic gradiometry data markedly illustrate the distributions of iron and steel artifacts, including iron in concrete foundations, individual iron or steel artifacts like nails, nuts and bolts, etc., and buried iron pipes. Some of the iron pipes illustrate a pattern of alternating positive and negative values, indicating strings of magnetic dipoles that probably correspond with pipe joints. A comparison against the conductivity image suggests that some pipes may not be of ferrous metal. Magnetometry is particularly sensitive to fired materials; some of the response near the buildings may therefore point to bricks or possibly burned earth from the 1921 fire. A neighborhood variance balancing filter was employed to reveal greater detail in areas of low magnetic activity and reduce high dynamic ranges elsewhere; the result was also subjected to a low-pass filter.

Magnetic Susceptibility Survey

Instrument: Geonics, Ltd. EM-38, in-phase component; Prospection depth: about 0.5 m; Sampling interval: 0.5 x 1.0 m; Area surveyed: 16,000 m2 (1.6 ha); Date of survey: 7/2002. Land Cover Type: Mowed Grass.

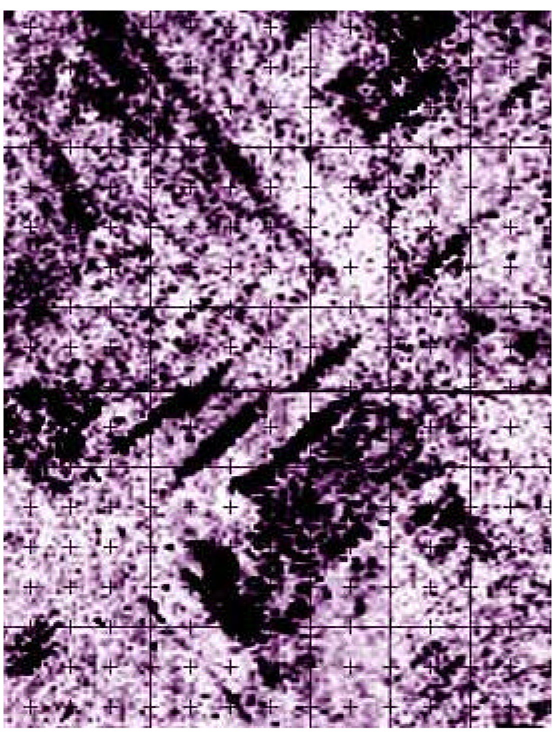


These data provide many new insights about the buried structures at Army City, possibly zones of brick debris, intensive burning, refuse dispersal, topsoil mounding or extraction. The raw magnetic susceptibility map does not illustrate the extreme anomalies caused by many of the numerous metal pipes that are seen in the other data sets. Initial processing of these data employed despiking, a high-pass filter to eliminate large zones of high measurement, and a low-pass filter for further noise suppression. A number of subtle details not apparent in the raw data are enhanced and it becomes possible to visualize the many features that exist within the saturated areas of high magnetic susceptibility.

Ground Penetrating Radar Survey

Instrument: Geophysical Survey Systems, Inc., SIR-2000 with 400 MHz transducer and survey wheel; Prospection depth: about 1.5 m; Sampling interval: 0.5 x 0.05 m; Area surveyed: 16,000 m2 (1.6 ha); Date of survey: 7/2002. Land Cover Type: Mowed Grass.

GPR was a big question at this site for it lies in conductive clay/silt soils in the Kansas River bottomlands that have frequently been subjected to flooding. This illustration is a



preliminary look at the GPR data, based on a composite of time slices resulting from the eight individual sub-blocks necessary to survey the entire area. All the slices are taken from the 5-15 nS range (TWTT; to perhaps .75 m depth). The slices are derived from the raw, unprocessed profiles, although background removal was performed. Seams are readily apparent between the eight blocks of data, as are stripes and other defects resulting from extreme temperatures and other circumstances (these defects will ultimately be corrected). Interestingly, a light rainstorm may actually have clarified results along the central area by exaggerating contrasts between building materials (e.g., concrete) and the surrounding soils. Whatever the case, this initial look suggests great promise in these data. In particular, many details in the building and nonbuilding areas are indicated that do not appear to occur in the initial data sets from the other instruments. Further data processing using a variety of common GPR transforms, gain balancing, and more detailed time-slicing will surely reveal many important insights, and at multiple depths.

An initial Army City report has been provided at http://www.cast.uark.edu/~kkvamme/geop/army_city.htm.

Geophysical Survey Silver Bluff Plantation (38AK7), Aiken County, South Carolina

Silver Bluff is located on the Savannah River in Aiken County, South Carolina. The bluff is about 15 miles downstream of Augusta, Georgia, and rises approximately nine meters above the river. The plantation, an area of 1,275 hectares, is part of a site owned by the National Audubon Society. The property is managed to demonstrate the compatibility of agriculture with wildlife and environmental concerns. Approximately 324 hectares are under cultivation while most of the area is comprised of woods and swamp.

Little is known of the early history of Silver Bluff. William Bartram, the pioneer naturalist, visited the site in 1776 and noted the presence of 'various monuments, terraces, areas, as well as traces of fortresses of regular formation.' George Galphin purchased the plantation in 1752 and established a trading post in the area. In 1975, after years of deterioration, the property was willed to the National Audubon Society. It was placed on the National Register of Historic Places in 1977.

As this report is being written, geophysical data is being acquired at Silver Bluff by Archaeo-Physics, LLC. Acquisition is scheduled to be completed by mid December 2002.

Geophysical Survey Kasita Town (9CE1), Fort Benning, Georgia

Lawson Army Airfield was built on site of Kashita (Cusseta) Town, which was the capital of the Lower Creek Nation before its removal. Much of what remained of the village was destroyed by the construction of Lawson Army Air Field before the site could be examined with modern archeological techniques.

As this report is being written, geophysical data is being acquired by Archaeo-Physics, LLC at Kasita Town. Acquisition is scheduled to be completed by mid December 2002.

Establish GIS Databases

The data sets for Whistling Elk and Mount Comfort Church have been placed at ftp://serdp@titan.cast.uark.edu, for project team access. As other data sets are completed they will be added.

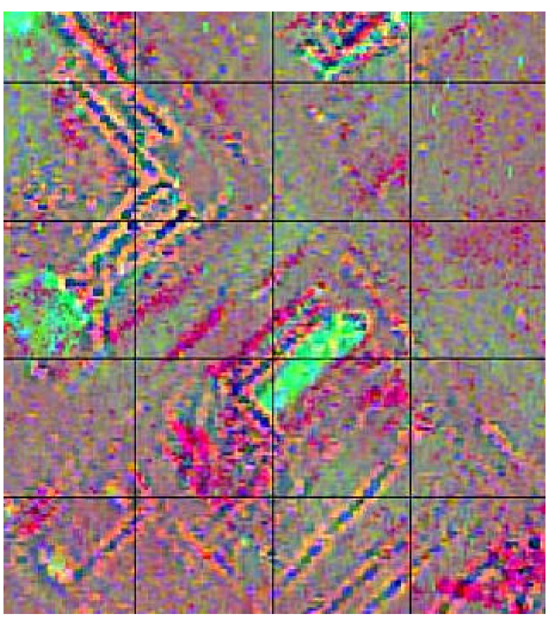
Preliminary Data Fusions

A variety of multi-layer mathematical, statistical, contextual, and other imaging methods will ultimately be employed to fuse the information content of these and the yet-to-be-gathered aerial and space-based data. The following presents some initial views of fusion of newly acquired Army City data using relatively simple methods applied to the unprocessed data. Better and much more sophisticated results are expected as the project progresses.

Fusion Using Computer Graphics

A simple visual illustration is provided here utilizing Adobe Photoshop software. The magnetic susceptibility image was superimposed on the resistance data, with opaqueness of both set at about 40%. Next, the magnetic gradiometry was superimposed and, finally, the soil conductivity data were added, both with similar levels of opaqueness. Each input image was color coded as in the above maps, resulting in the four-image composite

Principal Components Analysis



The five principal geophysical data sets were subjected to a principal components analysis that revealed common underlying dimensions of relationship. Three of the components gave clear interpretation: about 96% of the variance of one was derived solely from magnetometry, about 77% of the variance in another was equally derived from GPR-resistivity, and about 72% of the variance in a third was equally split between the conductivity-magnetic susceptibility data. These three components were respectively assigned the primary colors of blue, green, and red. The image at the left portrays the composite of the three color primaries.

Publications Appendix:

Ernenwein, Eileen G. and Kenneth L. Kvamme (2002). *Multi-dimensional Remote Sensing at Army City Kansas: A SERDP Project Fusing Ground Air, and Satellite Data.* Paper Presented at the Plains Anthropological Conference, Oklahoma City 2002.

Limp, W. F. Eileen Ernenwein, Kenneth L. Kvamme, Thomas Sever, Michael Hargrave and Lew Somers (2002). *New Approaches to the Use and Integration Of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation* Paper Presented at the SERDP/ESCP Conference. Washington, DC 2002.

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