NASA Remote Sensing Research As Applied to Archaeology

Marco J. Giardino, Ph.D.
Michael R. Thomas, Ph.D.
Earth Science Applications Directorate
NASA Stennis Space Center, MS

Introduction

The use of remotely sensed images is not new to archaeology. Ever since balloons and airplanes first flew cameras over archaeological sites, researchers have taken advantage of the elevated observation platforms to understand sites better. When viewed from above, crop marks, soil anomalies and buried features revealed new information that was not readily visible from ground level.

Since 1974 and initially under the leadership of Dr. Tom Sever, NASA's Stennis Space Center, located on the Mississippi Gulf Coast, pioneered and expanded the application of remote sensing to archaeological topics, including cultural resource management. Building on remote sensing activities initiated by the National Park Service (Lyons and Avery 1977), archaeologists increasingly used this technology to study the past in greater depth. By the early 1980s, there were sufficient accomplishments in the application of remote sensing to anthropology and archaeology that a chapter on the subject was included in fundamental remote sensing references (Ebert and Lyons 1983). Limp's 1993 review of remote sensing approaches to archaeology in the Southeastern United States documented the increasingly sophisticated application of the technology. These applications focus primarily on refining sampling strategies and on testing predictive models of site location, often based on environmental characteristics associated with specific site types.

Remote sensing technology and image analysis are currently undergoing a profound shift in emphasis from broad classification to detection, identification and condition of specific materials, both organic and inorganic. In the last few years, remote sensing platforms have grown increasingly capable and sophisticated. Sensors currently in use, or nearing deployment, offer significantly finer spatial and spectral resolutions than were previously available. Paired with new techniques of image analysis, this technology may make the direct detection of archaeological sites a realistic goal (Jones and Giardino 1997).

Facilitating the application of remote sensing digital image analysis are improvements in both hardware and commercially available software. Just during the last five years, computers capable of processing and storing the very large data sets that normally result from remote sensing missions (commonly, hundreds of megabytes to a few Gigabytes) have become widely available and relatively affordable. Similarly, commercial software such as ERDAS' Imagine, RSI's ENVI and ESRI's ArcView provide the tools necessary to conduct even the most quantitative remote sensing analysis. A fully operational setup costs less than $5000, a five-fold decrease from just a decade ago. Similarly, the cost and accessibility to relevant data sets have improved considerably as new commercial vendors have entered a market that was once serviced almost exclusively by Federal agencies.

A final obstacle to the broad application of remote sensing techniques has been the availability of an educated and trained workforce. Several academic departments, including many in archaeology, are offering courses in remote sensing. For example, the University of Mississippi (Ole Miss), in cooperation with NASA's Earth Science Applications Directorate at Stennis, is developing online coursework in remote sensing that leads to college degrees in the field. Additionally, NASA and Ole Miss have investigated numerous uses of remote sensing methods, particularly geophysical surveying and multispectral imagery, in addressing archaeological research issues.

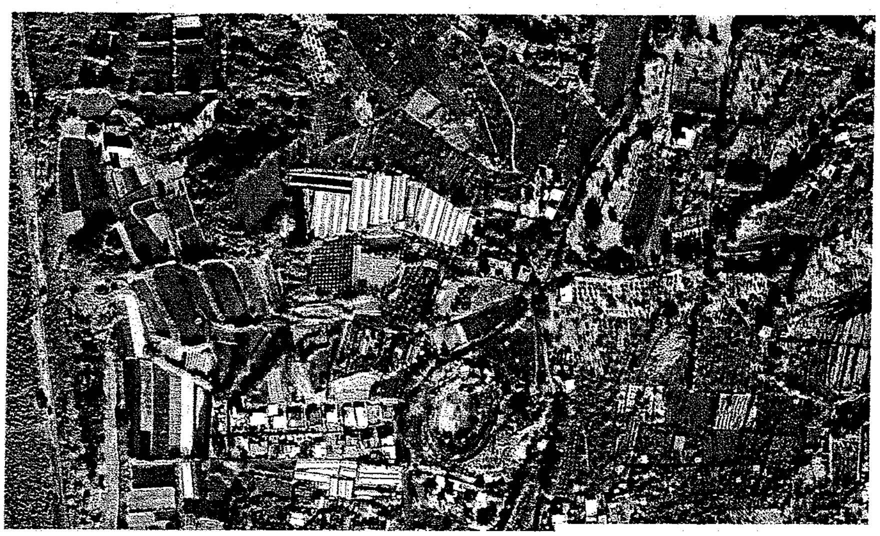
Spatial, Spectral and Temporal Resolution

Essential to the proper use of remotely sensed digital data is recognition of spatial, spectral and temporal resolutions of specific sensors as they apply to project requirements. Until most recently, high-spatial resolution data (less than 1-m to 5-m pixels or ground resolution element) was available only from airborne platforms. With the advent of the SPOT sensor and the industry-owned IKONOS and QuickBird instruments (the first by Space Imaging, Inc., and the other by DigitalGlobe, Inc.), high-spatial resolution data is now routinely available. IKONOS and Quick Bird data are accurate to 1 meter or less from orbit. Under ideal conditions, one could see the standard

2-meter square archaeological test unit from space. When combined with GIS methods, these data serve numerous archaeological applications such as site identification, delineation and exploration. Once properly processed, these images (as well as those taken from airborne platforms) provide highly detailed maps that serve as site baselines and can be used to test settlement pattern models.

NASA's Scientific Data Purchase Program

The availability of high-spatial resolution imagery for archaeological research has increased significantly because of NASA's Scientific Data Purchase (SDP) program. Instituted two years ago with Congressional assistance, the main objective of this project was to supply the science community's data needs through commercial vendors. Among the PIs served by this program were several archaeologists. As a result, high-spatial resolution, multispectral data were collected over numerous sites including Cumae in Campania, Koobi Fora in Kenya, ancient Troy in Asia Minor and Aksum in Ethiopia (see Figure 1). Reports from the scientists document a wide range of benefits derived from these data sets. Although this NASA program ends in October 2002, the data will continue to be available through commercial sources.



Space Imaging Inc., IKONOS 1-m panchromatic image of Cumae, Italy showing archaeological zone. Image acquired as part of a cooperative project between NASA/Stennis and UCLA.

Co-registering Historic Maps and Modern Digital Data.

Another application of high-spatial resolution multispectral data to archaeology involves the co-registration of historic plats and maps to modern imagery. This approach provides precise location of historic sites and produces very accurate site maps, particularly when the data are registered to them from active sensors like LIDARs and RADARs. Digital Elevation Models (DEMs) that are developed with the use of active sensors, when utilized in combination with X and Y coordinates derived from high spatial resolution imagery, produce accurate 3-D renderings of sites and the surrounding environment.

As part of the ongoing effort in support of the Lewis and Clark expedition bicentennial, remote sensing scientists at Stennis Space Center employ satellite imagery enhanced with elevation models to project the historic Clark maps onto the current topography, as imaged by LANDSAT and the AVHRR instruments. William Clark produced the vast majority of the maps collected during the Corps of Discovery Expedition (1804-1806). Co-registration of modern images with his historic maps, including the renderings of bluffs and other elevations, narrows the search for related historic localities, thus saving time, lessening subsoil disturbance and avoiding excessive transit through private lands.

NASA's current development of more accurate co-registration algorithms is being refined at the site of Gainesville, Mississippi, county seat of Hancock County during the mid-19th century. Gainesville was one of five historic towns that became part of the NASA Stennis Space Center Buffer Zone and Fee area in 1962 with the advent of the Saturn rocket program that launched the Apollo spacecrafts to the Moon. Gainesville, nominated to the National Register of Historic Places, is being studied and preserved through use of a wide range of remote sensing techniques. Maps of the site, developed through co-registration of historic maps to modern imagery, allow site development without impacting historic areas. Further, the products from this technique provide the base maps for planning surveys and rapidly evaluating fieldwork results (Figure 2).

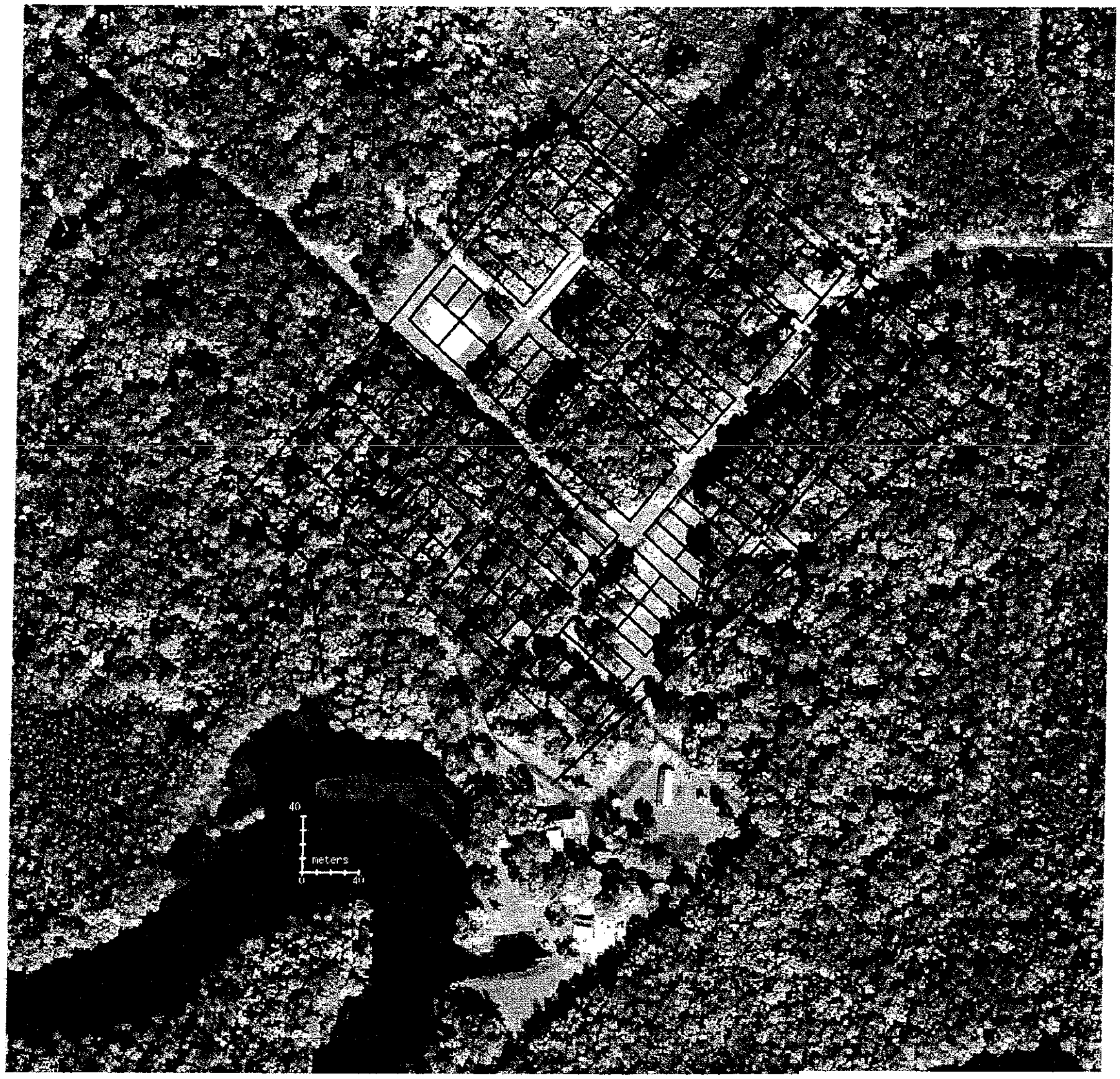


Figure 2. Space Imaging, Inc., IKONOS 1-m panchromatic of the Gainesville, Mississippi site, showing original 1837 plat co-registered over modern landscape.

Spectral analysis of remotely sensed data offers the possibility of efficiently identifying significant sites and features for testing and excavation. NASA is testing the effectiveness of new, passive hyperspectral instruments in archaeological research and applications. Hyperspectral sensors, whether flown in orbit (HYDICE, MODIS) or from airplanes (AVIRIS), segment energy into hundreds of narrow bands, dramatically increasing the spectral resolution of the digital data. Where multispectral instruments like

Landsat's TM and MSS sensors collect data in 10-micrometer wide bands, hyperspectral sensors dissect the incoming energy into numerous narrow bands, often as narrow at 10 nanometers.

In this way, hyperspectral sensors (most still being perfected) increase the potential for identifying plant species, as well as plant vigor (or lack thereof). Research in plant physiology indicates that variations in plant health can be detected in vegetation reflectance curves in specific regions of the red and near infrared regions of the electromagnetic spectrum (EMS). Organically enriched midden soils potentially promote vigorous plant growth. Differences in plant vigor that are not visually apparent can be detected with digital sensors, particularly in agricultural fields where most variation in plant reflectance should be due to soil and moisture conditions.

To test the efficacy of hyperspectral sensors to locate buried archaeological sites, researchers and engineers at NASA/ Stennis are studying several locations in the marshes of Southeast Louisiana. Here, large *Rangia* shell middens are covered with marsh grass and other vegetation. Shell mounds support a variety of shrubs and woody vines and a number of herbs and grasses that are not found in the marsh. Eleuterius and Otvos (1979) argue that red mulberry, coral bean and buckeye are consistently associated with sites both in the marshes and in other parts of the coastal zone. Although this is partially due to the site's increased elevation, these authors report that several of these species are calciphiles, whose presence is "favored and determined by the large amount of calcium" in clam shells (see also Limp, 1993:194).

Imagery over shell middens covered by a single specie of plant (i.e., *Spartina sp.*) is being studied to assess whether plants growing on these sites differ from those growing off the site by either growing more vigorously due to the increased organic content, or not growing as well due to the hard substrate. It may be possible to associate spectral variability in a homogenous plant stands like *Spartina* with the nature of the substrate. If these conditions can be resolved spectrally, than large regions can be examined using classification algorithms and digital processing.

Even in imagery with high-spatial resolution, most pixels will actually be a mixture of several different materials on the ground. For example, grasses, such as *Juncus* or *Spartina*, dominate a typical marsh pixel. However, the pixel may also contain water, soil, and perhaps other plant species. This means that the spectral values of any particular pixel are really composite values for each of the materials present in the pixel. It is important to realize that a pixel's values are simply the average of the reflectance of that pixel's constituents, weighted by the relative abundance of each material in the pixel. This fact has an exciting consequence; if the reflectance curves for the imaged materials are known, then the pixel's reflectance can be mathematically decomposed into the reflectance of its constituents. This provides a direct estimate of the abundance of each material on the ground (Jones and Giardino 1997).

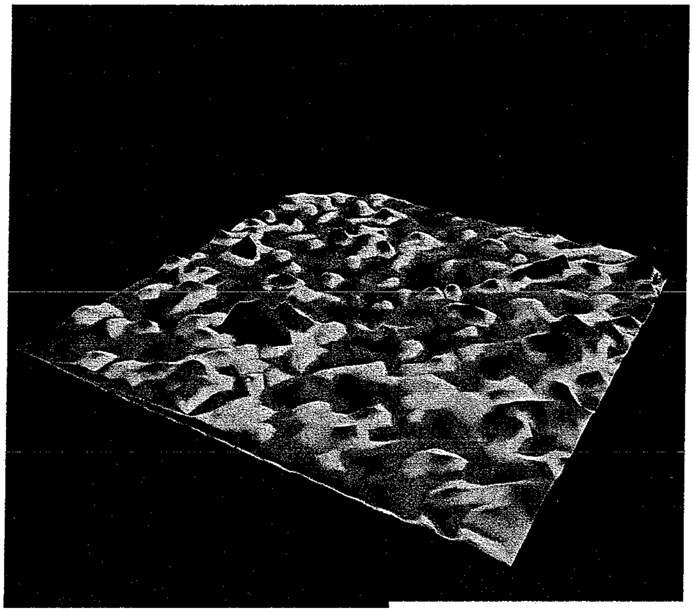
A similar application is being tried at the Gainesville site. Here spectral response curves derived both in the laboratory and from airborne hyperspectral instruments are collected to identify domesticated, decorative or border vegetation. The distribution of these plants provides important clues to the past location of house sites and land boundaries. During this project, hyperspectral data is merged with RADAR or LIDAR data to better define site elevations, a technique that will also be applied in the Louisiana marshes.

Geophysical Remote Sensing

The employment of geophysical remote sensing techniques (conductivity, resistivity, magnetometry and Ground Penetrating RADAR (GPR)) has deep roots in archaeology. NASA, in cooperation with the University of Mississippi, is testing the correlation between these data and data acquired from airborne and orbiting platforms. Particularly promising is the apparent correlation between GPR and thermal data (Weil and Graf 1994:117-126).

There appears to be a significant correlation between the ability of these two approaches to identify the same features, making the use of one over the other a strategic decision. As in other types of archaeological work using remote sensing, the area that can be investigated in a thorough and timely fashion increases exponentially over standard surveying techniques.

Much of the work conducted to date using this approach has focused on the Hollywood site in De Soto County, Mississippi. Other sites that have been investigated using both geophysical and thermal methods include the presidio at Los Adeas, the site of the Andrew Jackson, Jr., plantation in Waveland, Mississippi and the Broussard Mounds in Louisiana. Once again, advanced methods for fusing these types of data are being tested at the Gainesville site located within the boundaries of the Stennis Space Center (Figure 3).



Includes material © Space Imaging L.P

Figure 3. Ground Penetrating RADAR data imported into ERDAS Imagine and processed with 3-D module. Data from the historic Andrew Jackson Jr., plantation in Waveland, Mississippi, collected with a 500-MHz antenna. Red areas showing highest amplitude returns related to brick pylons and a possible well.

The primary mission of the NASA Earth Science Applications Directorate is to develop applications that employ remote sensing for a client group that includes State, Local, Tribal and Federal project managers. NASA's successful prototypes result in operational applications that make each recipient's job more effective and efficient. Those agencies and organizations that implement new remote sensing approaches to meet their objectives have an increasingly large pool of commercial data and software to successfully complete their work.

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