Chapter 3

Research

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INTRODUCTION

Historical and scientific research, interpretation to the public, and preserving U.S. cultural heritage for future generations are the primary purposes for preserving sites, structures, and landscapes. New technologies can improve the quality and quantity of research data gathered. They may also make possible the investigation of lines of evidence that were previously impossible. This chapter presents many of the technologies used for preservation research and discusses the issues they raise. For the purposes of analysis, OTA divided preservation research into the following steps, which do not necessarily represent an unfailing progression:

- discovery (survey, identification);
- documentation (mapping, physical investigations, recording); and
- analysis (evaluation).

Although for the purposes of analysis and discussion it is possible to separate these research steps, in practice, they are tightly interconnected. In order to construct a research plan for a project, it is necessary to decide prior to conducting fieldwork which technologies are to be used. The choices of technologies in turn depend on the research hypotheses the investigator wishes to explore, and on the results of preliminary archival research. in addition, many of the technologies employed for discovery are also useful or even essential for the documentation phase of research. It is therefore impossible completely to separate the discussion of the technologies for different phases.

The following discussion attempts to examine technologies in the research phase in which they are most often applied. The enumeration is far from comprehensive; rather the technologies have been chosen to illustrate the role of technology in preservation and are therefore representative of a much larger available array.

The research objectives of archaeology and the study of structures or landscapes are frequently very similar. Architectural historians and landscape architects often depend on archaeological research in analyzing historic structures or landscapes.[1] Archaeology, by the same token, uses historical research. This chapter focuses on the various technologies used by all preservation disciplines. Where necessary, the specific concerns of each discipline are discussed independently.

[1] See, for example, Paul Brace, "Archeological Resources and Land Development: A Guide to Assess Impact, " *Landscape Architecture Technical /formation Series 5, No. 1,* **September 1984.**

TECHNOLOGIES FOR DISCOVERY

The first step in gathering data is to locate cultural resources on the ground, under the ground, and under water. This section discusses several technologies (table 5) that are used primarily for identification and survey, Some, such as the remote sensing technologies, are often applied to the data-gathering phase of research or evaluation and assessment as well.

Archival Research and Oral Histories

Archival research and interviewing (oral history) are important first steps in the research process. Preliminary research, done with care and imagination, can save time and money as well as provide a focus for technological field work and a broad basis for the establishment of significance.

Table 5.—Representative Technologies for identification and Survey

Technical areas	Technologies
Remote sensing:	
Air	lidar, photography, radar
Space	radar, multispectral sensors
Geobased	magnetic detection, radar, seismic, thermography, X-ray, infrared, gamma-ray inspection
Marine	side-scan sonar, magnetometer, sub-bottom profiler, precision fathometer, electronic position finder, remotely operated vehicles
Terrestrial imaging	photography video photogrammetry
Computer technology and applications	theoretical modeling and prediction acquisition and interpretation of archival data management and dissemination of archival data mapping geographic information systems computer display
Social science techniques	oral history and folklore: tape recording photography video archival documentary research

SOURCE: Office of Technology Assessment.

Developments in archival technology of various sorts can make the records search more efficient and even more cost-effective than it is now (see *Chapter 5: Preservation Information).*

The technical questions involved with this type of historical research specifically concern methods of access to information in the institutions which house it, and ways of arranging data to make it usable for preliminary analysis and development of a research plan. Interviewing depends on the technologies for tape recording and archiving electronic storage media if oral history materials are to be retained.

Remote Sensing (Space, Aerial, and Geophysical Methods)

Remote sensing, as with most other technologies used in preservation, originated in other fields and is being adapted and molded to fit preservation requirements. The detail provided in this section illustrates the roles played by the natural sciences and engineering in providing technologies useful for preservation. Other technology discussions provide much less detail.

Remote sensing[2] from aircraft and from space, and other types of remote sensing techniques (table 6), such as ground-penetrating radar, hold great promise for the future of archaeology and the study of historic landscapes, because they are nondestructive and capable of analyzing vast areas quickly and accurately. Such techniques are less useful in the identification and survey of historic structures. Photogrammetry, which can be thought of as another form of remote sensing, has found greater utility for surveying historic structures, and is also used for archaeology and historic landscapes (discussed below),

Remote sensing technologies can aid substantially in recording accurately the positions of archaeological sites, and analyzing them within an environmental context. J They can also help in evaluating sites. They are useful both in predictive location modeling, and in onsite exploration in lieu of extensive testing. Remote sensing techniques employing aircraft and spacecraft have also been applied to the study of prehistoric and historic Landscapes.d

Remote Sensing From Aircraft and Spacecraft

Intrigued by the special perspective that balloons gave them, photographers began experimenting with aerial photography in the last cen-

[2] In general terms, remote sensing is the art of obtaining information about objects, areas, or phenomena through analyzing data gathered by devices placed at a distance from the subjects of study. Remote sensing may refer to sensing over short distances, as in medical or laboratory research applications using lasers, or over long distances as in environmental monitoring from spacecraft using advanced electro-optical instruments. Once the initial data are sensed, they must be analyzed and interpreted either visually or through sophisticated computer analysis.

[3] See, for example, *Remote Sensing: A Handbook for Archaeologists and Cultural Resource Managers, Contribution No. 4* of the Chaco Center, National Park Service and University of New Mexico, 1977. Also, Thomas R. Lyons and James **1. Ebert** (eds.), "Remote Sensing and Nondestructive Archeology," National Park Service Remote Sensing Division, 1978.

[4] Carole L. Crumley, "Archaeological Reconnaissance at Mont Dardon, France," *Archaeology,* May-June 1983, pp. 14-17, 20; and Scott L.H. Madry, "Remote Sensing in Archaeology," *Archaeology,* May-June 1983, pp. 18-19.

Table 6.—Remote Sensing Instruments[a]

Type of Instrument	Comments
Spacecraft:	
Multispectral scanner	U.S. Landsat (resolution 80 meters; 3 spectral bands)
Thematic Mapper	U.S. Landsat (resolution 30 meters; 7 spectral bands)
Shuttle Imaging Radar[b]	Carried on Shuttle
SPOT	French SPOT (resolution 20 meters in 3 spectral bands; 10 meters in B&W)
Aircraft:	
Photographic camera	
Multispectral scanner	
Thermal infrared mapper	
Geophysical techniques:	
Proton magnetometer	
Soil conductivity meter	
Soil resistivity meter	
Ground-penetrating radar	
Metal detectors	
Terrestrial photogrammetry:	
Precision camera	
Stereo comparator	
Stereo analog plotter	Needs precision cameras
Stereo analytical plotter	Uses digital techniques and a computer

[a]See Robert Colwell, editor-in-chief, *Manual of Remote Sensing* (Falls Church, VA: American Society of Photogrammetry, 1983)
[b]Charles Elachi, JoBea Cimino, and M. Settle, "Overview of the Shuttle Imaging Radar-B Preliminary Results," *Science* 232 (1966), pp 1511-1516

SOURCE: Office of Technology Assessment

tury. They continued their experimentation from aircraft soon after the first airplane was flown. Aerial photography has since become an important part of soil conservation, flood control, highway design, city and county planning, and, of course, military reconnaissance. The National Archives and Records Administration, and the Agricultural Stabilization and Conservation Service of the Department of Agriculture, maintain extensive collections of aerial photographs of the United States. USDA field offices may hold the most current photos for their localities.

The scientific and applications-oriented communities recognized the potential value of sensing the Earth's surface from space early in the development of the Nation's space program. Space remote sensing was an obvious extension of remote sensing from balloons and aircraft. However, the expense of returning film from space,[5] the need to manipulate data in a computer, and the desire to sense Earth in a variety of wavelengths led to the development of electronic multispectral scanners that operate in a variety of colors, or spectral bands (figure 1). The United States launched its first land remote sensing satellite in 1972, which carried an experimental multispectral scanner. Landsat 5, the fifth in the series of civilian land remote sensing satellite, is now providing high-quality images of Earth on a regular basis.[6] The resulting electronic signals are transmitted to Earth where they are converted into data susceptible to computer manipulation.

For purposes of preservation, the ability of remotely sensed data from space to resolve objects the size of individual sites or structures has been highly limited in the past.[7] However, the SPOT system recently deployed by the French achieves ground resolutions of 20 meters (65.6 ft.) in three spectral bands, and 10 meters (32.8 ft.) in black and white. Data of such relatively high spatial resolution, when processed with other data, such as those relating to soils and color, will be highly effective in providing information concerning preservation. Recent developments in computer image analysis can improve on the resolution of such images by at least a factor of 2.[8]

Of more importance to archaeology, because of their better ground resolution and ability to sense in many spectral bands, are multispectral scanners for aircraft. Originally developed as part of the testing program for the Landsat satellites, they have proved extremely successful in aircraft applications.[9] With them, surface resolutions of a few feet can be achieved in many different spec-

[5]The early reconnaissance satellites discharged canisters of film, which were then caught by specially equipped aircraft. Such methods are now being explored for possible civilian use for special projects, such as crop or forest inspection, requiring high resolution and quick return of data.

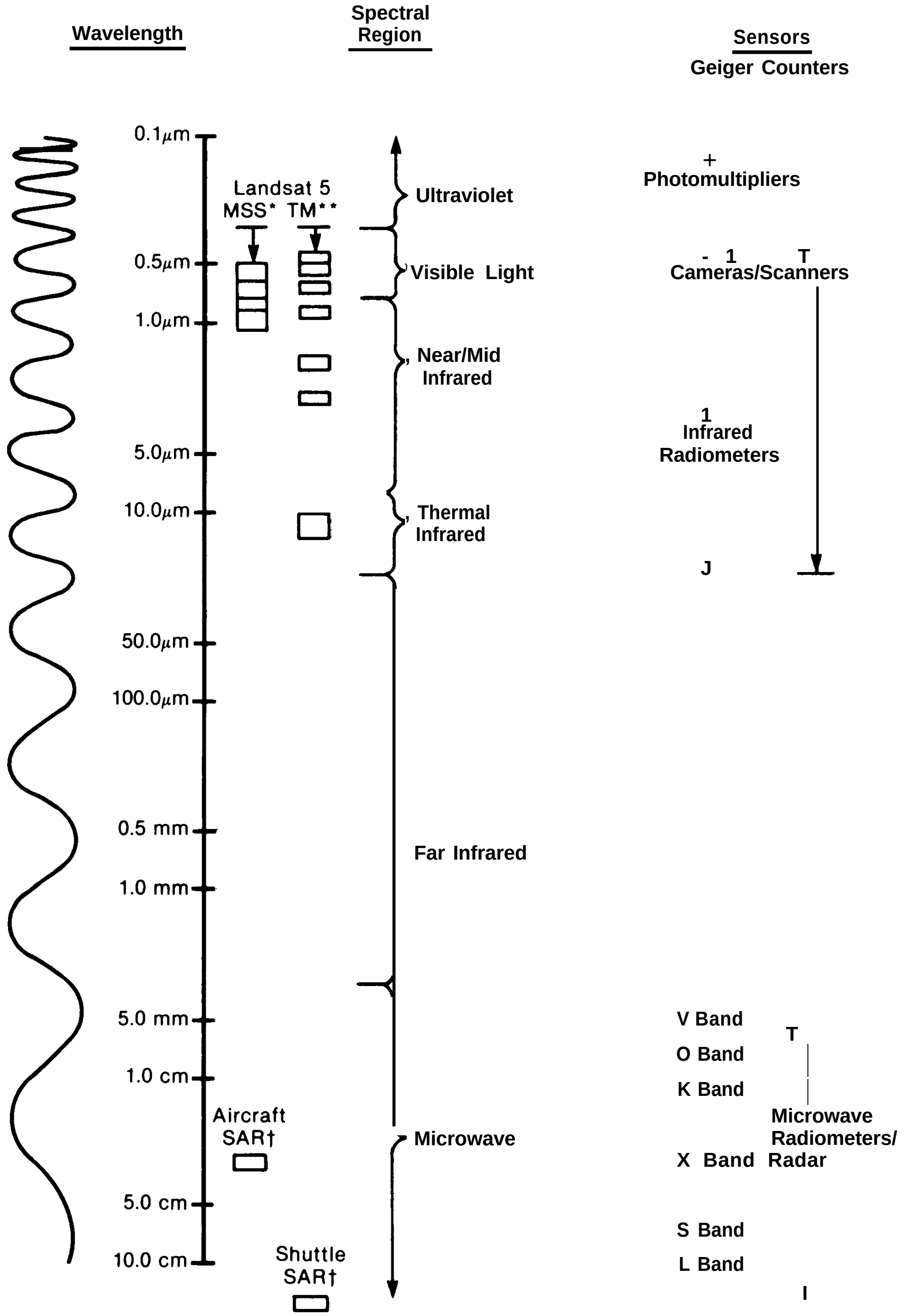
[6]See U.S. Congress, Office of Technology Assessment, *Remote Sensing and the Private Sector: Issues for Discussion,* OTA-TM-ISC-20 (Washington, DC: U.S. Government Printing Office, March 1984), for a discussion of some of the many uses of remotely sensed data. See also U.S. Congress, Office of Technology Assessment, *International Cooperation and Competition in Civilian Space Activities,* OTA-ISC-239 (Washington, DC: U.S. Government Printing Office, July 1985), ch. 7.

[7]For example, the multi spectral scanner on the U.S. Landsat has a resolution limit of 80 meters, and the Thematic Mapper a resolution limit of 30 meters.

[8]William J. Broad, "New Power Lets Computer Depict Images Invisible to Eye," New *York Times,* Sept. *2,* 1986.

[9]Thomas Sever and James Weisman, "Remote Sensing and Archaeology: Potential for the Future," National Aeronautics and Space Administration, Earth Resources Laboratory, January 1985.

Figure 1.—Diagram of the Electromagnetic Spectrum



● MSS: Multispectral Scanner
●● TM: Thematic Mapper
†SAR: Synthetic Aperature Radar

SOURCE: National Aeronautics and Space Administration tral bands. High surface resolution is important in examining details of a site. The different spectral bands are extremely helpful in locating sites according to vegetation differences that appear near human habitations.

To make effective use of archaeological remote sensing, one needs first to understand the general features of the region's archaeology. It is then possible to incorporate remote sensing into a research scheme, keeping in mind the limitations as well as the advantages of the technology, For example, in many cases it is not ever-t possible to detect the archaeological sites directly on remotely sensed data. Sites may consist of small piles of stone, or pottery, or may be lost in the subsequent vegetation. Therefore, other indicators, such as vegetation, are necessary.[10]

Remote sensing is potentially useful for examining the environmental effects on a site. It can also be used effectively for investigating how well we can discover certain categories of sites. Remote sensing can also be useful for logistics—finding your way in the field, locating sample units, etc. Nevertheless, remote sensing cannot replace archival survey or traditional walking survey and more intensive archaeological activities, including excavation.

In the past, to use remotely sensed data to find sites, it was necessary to hand digitize all the available surface information into a Geographical information System (see Documentation and Analysis section for a discussion of this technique), then put known sites on the map, and look for commonalities in the surface features that would indicate new sites. By putting layers of information together, it is possible to extract general rules for the likelihood of finding unknown sites.[11] Such a method will not find sites, but it does help predict where they are more likely to be. Now this can be done automatically.

In a related development, optical engineers have developed a relatively inexpensive optical digitizer. Among other things, such devices have helped to analyze handwriting and to translate handwritten material to printed form from 19th century ledgers kept by agents of the Bureau of Indian Affairs, for example (see *Chapter* 5: *Preservation Information).* For archaeology, similar techniques can be applied, for example, to hieroglyph on damaged Mayan carvings, allowing experts in Mayan writing to interpret details of the signs invisible to the naked eye.[12]

Although archaeologists find remote sensing techniques extremely useful in locating individual sites, and exploring patterns of human settlement, they can also use such techniques to choose the best sites for later excavation. However, the methods of distinguishing among a group of suitable sites are still under development and need to be refined before remote sensing can be fully applied to this process.

Remote sensing technologies that hold the greatest future promise for improving site and landscape discovery, identification, and evaluation are those that provide a broad, overall (synoptic) view and record data in digital form for direct computer processing (e. g., multispectral scanners on spacecraft or aircraft). However, for most applications today, aerial photographs are extremely valuable and much cheaper than multispectral scanners. They can also be used for identifying and assisting in determining the significance of historic structures.

Research Needs

- *More effective use of aerial photography:* Photography is still the most useful and inexpensive data source with the highest resolution, both spatial and temporal. Yet in some regions we do not always understand at what time of year and under what conditions (e.g., in terms of the growing cycles of plants) to use infrared photography for best results in archaeology.[13] Recently developed

[10] This was demonstrated recently in an effort to find Mayan cities in the Yucatan peninsula using data acquired by the Landsat Thematic Mapper. Ramon trees (*Brosinum alacastrum*) grow preferentially in the central plazas of ancient Mayan cities. The different color channels of the Thematic Mapper can be used to detect Ramon trees, though the instrument will not detect the plazas directly.

[11] See, for example, Jay F. Custer, et al., "Application of Landsat Data and Synoptic Remote Sensing to Predictive Models for Prehistoric Archaeological Sites: An Example From the Delaware Coastal Plain, " *American Antiquity 51, 1986,* pp. 572-588.

[12] Thomas Sever, NASA, personal communication, 1985.

[13] See Thomas E. Davidson and Richard Hughes, "Aerial Photog-

(continued on next page)

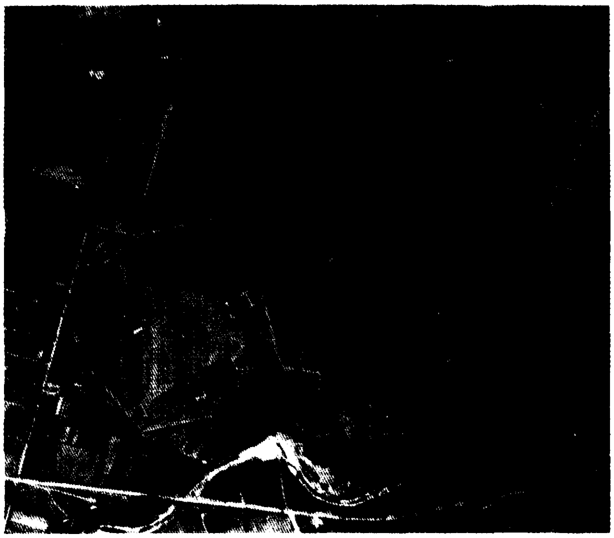
digitizing methods (see below in section on photogrammetry) may make such photographs of much greater utility in archaeological research. It **will be important to conduct systematic research to determine the most effective times and ways to use aerial photographic techniques.** For example, in some investigations, it may be cost-effective to suspend a radio-controlled camera from an inflatable blimp to document and map sites, structures, or even landscapes.[14]

- *The use of historical aerial photographs for monitoring site condition through time:* Many of the older aerial photographs (from files of the U.S. Department of Agriculture's Soil Conservation Service, and in the Cartographic Branch of the National Archives and Record Administration, for example) may provide useful historical information on sites, but they have not been fully exploited. Aerial photographs have been taken of most places in the United States many times since the early 193os, and provide a unique record of changes in the landscape and in archaeological materials on and in it since that time. Not only can the use of such photos serve to alert managers about impending changes or destruction of archaeological sites and landscapes from natural or human causes, they can also point the way to understanding a variety of natural processes that affect them. For archaeology, historic aerial photographs can assist in understanding those processes that affect all archaeological materials from the time they are deposited by their original users to when they are found by archaeologists.

  For example, a current study being conducted for the Army Corps of Engineers,[15] focuses on understanding types and rates of erosion affecting large archaeological sites located on Corps of Engineers' reservoirs along the upper Missouri River, Some of the study sites are covered by as many as *26* series of aerial photographs taken at different times of the day and year and at various scales and photographic emulsions (black and white, color, color infrared) since 1933. The study will compare erosion rates calculated from the photographs with reservoir dynamics, climate, and landform to arrive at erosion projections for use in directing future erosion control at the sites. Studies such as this could be effective for erosion of historic landscapes and for erosion patterns around historic structures.

- *Continued study of the spectral bands most effective for preservation:* The spectral bands for aerial scanning spectrometers and for space systems have been chosen for their utility in minerals detection and in the management of agricultural or forestry resources.

Newa k Earth Wo ks Newa k Oh o



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H w H w m d rs g 9 0 m m g w 0 g S m re w Eastern United States often enclose areas of up to 50 acres.

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raphy and the Search for Chicone Indian Town, " *Archaeology 39,* 1986, pp. 58, 59, 76, for a description of recent research using infrared aerial photography at different seasons to search for the remains of a Nanticoke Indian town in Delaware. One of the goals of their research was to demonstrate the effectiveness of aerial infrared techniques for use in the Middle Atlantic States.

[14] J. Wilson Myers and Eleanor Emlen Myers, "Aerial Photography at Ancient Sites, " *Context* 4, Boston University Center for Archaeological Studies, 1958, pp. 1-5.

[15] For the Vicksburg Waterways Experiment Station, by Ebert & Associates, Albuquerque, NM.

The spectral bands that best display certain kinds of archaeological sites may be different from those that are best for forestry or agriculture. Determining how best to use these or other spectral bands for the special needs of preservation will require continued study.

Such considerations apply especially to the use of optical scanners. To be most efficient for preservation, the total system (scanner and associated computer software) should be designed for the specific preservation need. For example, the best mix of spectral bands and ground resolution to use in studying structures is likely to be different from the mix for agriculture or minerals exploration. Because of the different soils and vegetation, even regional differences may dictate different approaches to optical scanners. However, the use of existing systems, though not designed specifically for preservation work, may be more cost-effective, at least in the short term.

- *Problem orientation—matching preservation data needs with appropriate remote sensing technology:* As in the application of any technology, a problem must first be defined and the data needs appropriate to its solution chosen realistically. This requires a sound understanding of the limitations as well as the possibilities offered by technologies.

  Many remote sensing technologies have not been explored systematically to determine their potentials and limitations for archaeology. However, they may yield unimagined new data. For example, only one systematic series of experiments in the use of optimum conditions for thermal scanning for the discovery of archaeological remains has been conducted.[16] in that set of experiments, using the French ARIES airborne thermal scanner, the experimenters flew the scanner many times over several valleys in France where Celtic field boundaries were known to exist but were not obvious either with ground survey or on conventional aerial photographs. In each overflight, they recorded cloud conditions, air temperature, and soil temperature, as well as the recent history of these quantities. Their experiments demonstrated that only during very short "windows" of a few hours every several months was thermal scanning useful for locating such features. Its application to different sorts of features would require different conditions.

Costs.–Costs for processing remotely sensed data are decreasing rapidly, so the data will be easier and cheaper to use in the near future. Until recently, users of data sensed from space (e. g., on the Landsat system) have had to rely on expensive mainframe computers to process the data. It is now possible to purchase a microcomputer system (including both hardware and software) to analyze such data for less than $25,000.[17]

Users of remotely sensed data must always weigh the costs associated with analyzing large areas against the spatial and spectral resolution desired. The greater the resolution, the more expensive the processing. Because the number of data elements per area increases by the square of the resolution, the costs of processing information increase nearly by the same rate. It is therefore important to choose the spatial resolution most appropriate for the application. For certain problems, enhanced spectral information may be more important than greater spatial resolution. For example, particular spectral bands may contain information that enables one to determine, for example, plant type, the presence of phosphates in the soil, or the presence of trapped moisture. All three signs may indicate the presence of subsurface features otherwise invisible.

Geophysical Remote Sensing

Depending on the nature and depth of burial, such instruments can find and explore buried or partially buried archaeological sites without

[16] See M.C. Perisset and A. Tabbagh, "Interpretation of Thermal Prospection on Bare Soils," *Archaeometry 23,* 1981, pp. 169-188.

[17] See the discussion on this and related topics concerning the development of lower cost processing for remotely sensed data from space in an earlier OTA report entitled *International Cooperation and Competition in Civilian Space Activities,* OTA-ISC-239 (Washington, DC: U.S. Government Printing Office, June 1985), ch. 7.

damaging them by excavation.[18] Some of these sites occasionally include extraordinarily well-preserved sites that have been hidden from looters and occasional collectors. As many of the sites found by such methods are not threatened by looting, erosion, or other natural or human threats, such methods will become increasingly important as the more accessible sites are destroyed.

Proton Magnetometer.[19]–The proton magnetometer is used to measure extremely small changes in the local magnetic field near archaeological features caused by small differences between the magnetic characteristics of buried structural features or material and the surrounding soil.

The ability to measure such differences depends directly on the fact that protons, basic building blocks of the atom, tend to align themselves in the direction of the Earth's magnetic field. The stone or fired clay of artificial subsurface features produce magnetic anomalies in the local magnetic field that can be measured by detecting small changes in the tilt of protons as they spin in the magnetic field of the Earth. As the investigator moves the instrument across the Earth in a grid pattern, the anomalies show up as slight changes in the direction and intensity of the local magnetic field. Plotting such anomalies on a grid leads to a rough map of the subsurface features. Brick, fire hearths, and iron-bearing materials show up best in this technique, although some earthen features are also measurable.

This method can markedly improve the efficiency of locating some subsurface archaeological features by avoiding the necessity for digging test pits. Sites can be investigated at rates of 10 minutes per square meter. The method is particularly useful for shallow subsurface features. However, small, deeply buried features are extremely difficult to detect with this technique, because the alterations of the Earth's magnetic field produced by these features are small.

Soil Resistivity Meter.– Different soils exhibit different resistance to the passage of electric current, primarily as a result of their varied water content. This method involves measuring the electrical resistance of soil to the application of a small current between two electrodes inserted in the ground. Archaeological features tend to have a different water content than the surrounding soil.

Although this technique is much simpler and cheaper than radar or magnetometer methods, it is much more tedious and time-consuming because it requires placing electrodes in the Earth at each point of a grid pattern over the archaeological features under study. However, because it is simpler and can be used near buildings, power cables, surface iron, and other materials that would make the use of magnetometers impossible, it is sometimes the appropriate choice. It can therefore be used more readily in urban settings.

Soil Conductivity Meter.–This instrument is similar to the soil resistivity meter, but measures instead the conductivity of the soil, using electromagnetic techniques. In one form, developed by Geonics Ltd., of Canada, the device uses a varying magnetic field to induce currents in the ground below the instrument that are proportional to the soil's conductivity. These currents in turn generate magnetic fields that can be measured with the instrument. The major advantage of such an instrument is that it does not require probes and can therefore be used to map terrain as quickly as an operator can walk across it.[20]

Ground-Penetrating Radar.–Ground-penetrating radar instruments emit microwave pulses at frequencies that will radiate below the Earth's surface. A receiving antenna carried along the surface with the instrument on a cart or sled detects echoes from buried features or discontinuities in the soil. The time of return of the echo determines how deep the feature is. This method

[18] See Payson **D. Sheets,** "Geophysical Exploration for Ancient Maya Housing at Ceren, El Salvador," *National Geographic Society Research Report: 1979 Projects,* **pp. 645-656,** for a discussion of the use of geophysical exploration techniques in volcanic tephra.

[19] For descriptions of this and other geophysical techniques, see M.S. Tite, *Methods of Physical Examination in Archaeology* (London and New York: Seminar Press, 1972). See also John W. Weymouth, "Ch. 2: Archaeological Site Surveying Program at the University of Nebraska," *Society of Exploration Geophysicists Technical Program Abstracts,* Dec. 1-6, 1984{ pp. 191-193.

[20] J. D. McNeill, "Electrical Conductivity of Soils and Rocks, " Technical Note TN-5, Geonics Ltd., Ontario, Canada, October 1980.

works particularly well for detecting buried walls, floors, and foundations. It requires sharp differences in the radar reflecting characteristics between artificial features and the earth surrounding them. Concentrations of brick and metal produce strong echoes.

Considerable experimentation may be necessary to determine which frequencies are appropriate for the particular region and sites under investigation. For example, one investigator found that in investigating two different sites in Canada, operating with antennas at a frequency of 350 megahertz provided the ability to penetrate from 1 to 3 meters depth, and a resolution of position in the ground of a few centimeters. Using antennas capable of operating at 100 megahertz would penetrate much deeper, up to depths of 30 or or 40 meters, but with resolutions no better than one-fourth of a meter. The latter instrument is therefore more appropriate for survey, the former for detailed investigations of features relatively near the surface, zl Another investigator, working in south-central Ohio, found good results using transmission frequencies of 650 megahertz.[22]

Metal Detectors.– Electromagnetic metal detectors, of the type often used to find buried metal pipes and cables, and to detect military mines or buried bombs, can also be used in archaeological contexts where metal-bearing artifacts or features are expected. With these instruments, a changing magnetic field produced by the instrument induces small currents, called eddy currents, in buried metal objects, which can then be detected by a receiving coil connected to the instrument. The more sensitive instruments of this type can detect coins or small metal artifacts in graves. They have been successfully used to locate artifacts on historic battlefields.[23] The metal detector is an example of a technology that is also inexpensively available to relic hunters, some of whom may use them on public lands.[24] (See *Chapter 4: Restoration, Conservation, Maintenance, and Protection* for discussion of such issues.)

Proton magnetometers and other site-scale instruments, such as ground-penetrating radar, can be used to define the structure and limits of a site, and to plan excavation or sampling. For example, they have been successfully used to map otherwise nearly invisible features of prehistoric earthwork remnants in central Ohio.[25] Although the information provided by such methods cannot substitute for a detailed excavation, they may provide important information concerning where to excavate within a large structure or site. Additionally, where the form, orientation, or location of a site is the information sought, such methods are far less costly and take less time than digging test pits or trenches.

To make these methods most useful, archaeologists need to refine their understanding of which of these technologies to apply to a particular geographic area, soil type, or season. For example, the proton magnetometer is most useful where the archaeological features produce relatively strong alterations of the Earth's magnetic field. Ground-penetrating radar can often be used over frozen ground at times of the year when the probes required with soil resistivity, or soil conductivity meters cannot be inserted in the soil. In some cases, the application of several different instruments may be appropriate as the data they generate are often complementary. In addition, for these as well as many other archaeological methods, "a sound knowledge of the living processes of the historic and prehistoric inhabitants that occupied the site and the types of features that they might have created are invaluable for the design of data collection procedures and subsequent interpretation of the data, "[26]

[21] C. J. Vaughan, "Ground-Penetrating Radar Surveys Used in Archaeological Investigations: Two Case Histories, " Society *of Exploration Geophysicists Technical Program Abstracts,* Dec. 1-6, 1984, pp. 195-197.

[22] N'omi Greber, ''Salvaging Clues to a Prehistoric Culture, ' The *Gamut,* Cleveland State University, spring/summer 1981, pp. 35-45.

[23] Stephen W. Sylvia and Michael J. O'Donnell, "underground Warfare: Hunting for Relics on Civil War Battlefields, " *Man At Arms Magazine,* July/August 1979.

[24] Recently, several men were apprehended and convicted of looting the Richmond Battlefield of Civil War relics. They used a metal detector.

[25] See N'omi Greber, "Geophysical Remote Sensing at Archaeological Sites in Ohio: A Case History, " *Society of Exploration Geophysicists Technical Program Abstracts,* Dec. 1-6, 1984, pp. 185-189, for a comparison of the use of resistivity and ground-penetrating radar.

[26] Robert Huggins, "Some Design Considerations for Undertaking a Magnetic Survey for Archaeological Resources, " *Society ot' Exploration Geophysicists Technical Program Abstracts,* Dec. 1-6, 1984, pp. 210212.

Several lost historic towns in Mississippi were also located in a similar way. When the towns were inhabited, people planted crepe myrtle and osage orange around their homes. Though all visible signs of dwellings have since disappeared, the trees still exist and because of how they show up in the different spectral bands imaged by the Thematic Mapper, they can be detected and separated from the other vegetation .*7

Terrestrial Photography and Photogrammetry

Although terrestrial photography and photogrammetry are closely related to remote sensing, they are generally applied over much smaller areas and at closer ranges than aerial and space or geophysical methods. Such methods include stereo photogrammetry as well as conventional photographic recording of structures[28] and landscapes, archaeological sites, and rock art sites.

Traditional Stereophotogrammetric Methods (Photo-theodolite) .–Traditional methods have made use of a pair of large (9x9 inch) or medium format (4x5 inch or 21/4 x 31/4 inch), high precision photographic cameras set about 40 inches apart. Enlarged stereo pairs of photographic images of the scene under study are then placed in an optical comparator, allowing a viewer to see them as a single, three-dimensional image.[29]

In the simplest available method, a highly trained operator traces the object of interest in the comparator, recording contours of the three-dimensional image, which are in turn transmitted mechanically to a drafting table, Photo-theodolites to meet several different photogrammetric needs are available. Such equipment can be made more effective by adding such equipment as advanced plotters using microcomputers, color-graphic video terminals, and tape or disk storage.

Until recently, photogrammetric recording has been relatively expensive. Although basic equipment can be acquired for about $60,000, a complete, high-accuracy, system can cost as much as $1 million. Stereo-plotters alone may cost nearly $250,000. Some architectural and engineering firms have simply been unable to absorb such an expense. While traditional equipment costs have been stabilizing, labor costs have risen.

In addition, concern over rapid obsolescence has discouraged investment in standard photogrammetric equipment. Currently, the "bread and butter work, " much of which is aerial, but which uses the much the same stereo-plotters and comparators, is conducted for industrial quality control and State highway and transportation departments.

Recent innovations that depend heavily on digital computer applications rather than precision optics to achieve accuracy, are dramatically lowering the costs of precision photogrammetry. The following two examples illustrate this trend. Even if new developments are still inappropriate for certain applications where extremely high accuracy is required, they will be useful in supplementing traditional methods.

Stereo Analytic Plotting Systems.–Stereo analytic systems represent a simplified approach to photogrammetry.[30] Like traditional stereo photogrammetric methods, they use photography as the basis for making three-dimensional measurements. However, they can often use 35mm stereo slides, black and white, or color film, taken with normal commercial lenses, instead of the larger format photographs used in traditional instruments. The technology has aided in preserving accurate images of site features, particularly those of a subtle nature, which will be destroyed by the process of excavation, as well as of objects before their removal from the archaeological context.

Such instruments allow an operator to examine a stereo pair of color slides and, to record the

[27] Thomas Sever, NASA, personal communication, 1985.

[28] See, for example, U. S. Department of the Interior, National park Service, Preservation Assistance Division, "Using Photogrammetry To Monitor Materials Deterioration and Structural Problems on Historic Buildings: The Dorchester Heights Monument: A Case Study" (Washington, DC: no date).

[29] See Hans Foramitti, "Classical and Photogrammetric Methods Used in Surveying Architectural Monuments, " *Preserving Monuments and Historic Buildings,* Museums and Monuments Series 14 (Paris: UNESCO, 1972).

[30] One such instrument is made by H. Dell Foster Associates of San Antonio, TX, for the American Schools of Oriental Research and field tested by archaeologists working in the Middle East. See "Computers Aid Study of Ancient Artifacts, " New *York Times,* Aug. 13, 1985, for a description of the H. Dell Foster, MACO 35/70 system. It uses either 35mm or 70mm film.

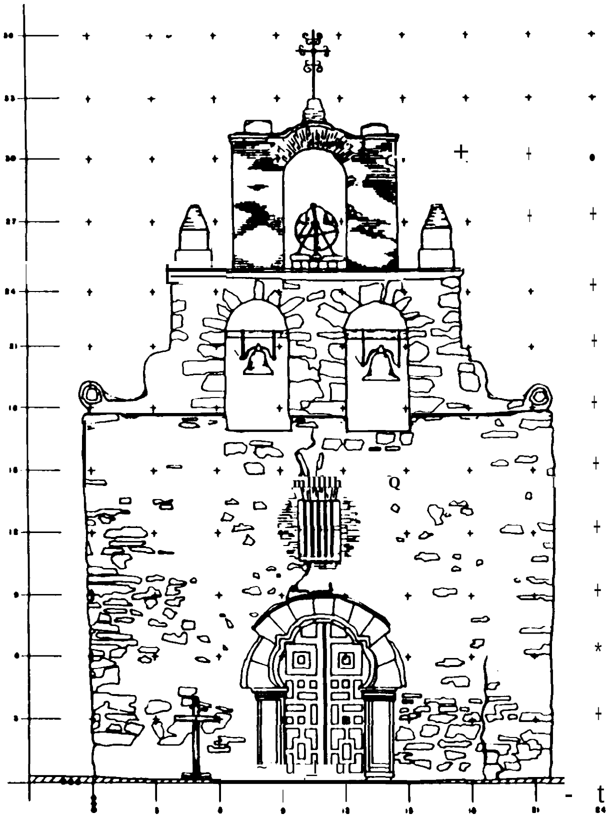

Photo credit: Southwest Reg/on, Nationa/ Park Serwce

Drawing of Mission Espada, San Antonio, Texas, from stereo photographs using the MACO 35/70 analytic stereo-plotter.

three-dimensional positions of points within the scene directly on an associated computer, which can be a minicomputer or inexpensive microcomputer. Computer software corrects for lens and image errors and produces high precision measurements of features selected by the operator. One of the advantages of analytic systems is that they require less highly trained operators than traditional photogrammetric systems.

The NPS Southwest Regional Office is using a stereo analytic system to prepare drawings of buildings under its care, assess the condition of ruined pueblos and mission buildings, and record the petroglyphs at Inscription Rock, El Morro National Monument.

Computer Image Analysis.–Technicians at NASA's Earth Resources Laboratory in Bay St. Louis, Mississippi, are developing a system that should eventually circumvent the need for a trained technician to examine the stereo image directly.[31] Instead, through a technique called digital scanning, each photograph is optically scanned by an instrument that converts the photographic density at each point in both stereo photographs to a number proportional to the density and stores it in a computer. Within a few minutes, the device can digitize and store the information from images as large as 18 inches on a side. Computer software then corrects for any photographic distortions and compares the information on the two photographs.

When analyzing the images, by searching for edges in the image, much the way a human operator of a stereo comparator does, the computer can generate a three-dimensional line drawing of the building or object in the pair of photographs. The resultant drawing can then be printed out on a computer-driven plotter. At the present time, the technique requires a mainframe computer. However, the associated digital scanner is relatively inexpensive. The accuracy of such a system is limited primarily by the inherent accuracy of the photographic images, and by the accuracy of the digital scanner. It should be able to generate high-quality drawings from high-quality photographs.

These promising applications, however, have barely begun to affect the way photogrammetric recording is undertaken in historic preservation. Architectural photogrammetry has not been developed in the United States at a level comparable to that found in countries such as Austria, France, the Federal Republic of Germany, and in other European countries. This is in part because the United States has few facilities for training in the use of these methods, and in part because the use of accurate measured drawings is given relatively low priority in the preservation of structures and landscapes. High costs have also been cited as an important factor, yet other countries have found them to be cost-effective for generating highly accurate drawings.

Even if a company has already invested in *basic* equipment and trained staff, the use of architectural photogrammetry is cost-effective, as such methods lead to a marked increase in accuracy

[31] OTA site visit, March 1986.

and productivity over the labor-intensive requirements for preparing measured drawings using traditional methods depending on direct measurements. For this reason developing countries such as Indonesia, Peru, and Turkey now have their own photogrammetric services.

There is a critical need for improved information exchanges between the preservation community and the American Society of Photogrammetry and Remote Sensing, which publishes detailed technical information. The cheaper, easier-to-use, photogrammetric methods resulting from the development of analytical instruments and large-image digitizers may represent a significant breakthrough, but the benefits are still largely unrealized.[32]

Video Tape and Optical Disk Methods

Video and optical disk technologies can both be powerful tools for survey and identification. Video techniques have proved especially helpful in the survey of underwater archaeological resources, and for rapid survey of city neighborhoods and historic structures.[33] Optical disks can be used to store video, film, and still images of cultural resources for rapid retrieval and comparison (see Chapter 5: *Preservation Information).*

Issues in Remote Sensing

Training in Remote Sensing Techniques.– Though many of the recently developed remote sensing techniques are extremely powerful, preservation professionals have not used them effectively, primarily because they are often unfamiliar with the utility of such techniques, and lack training in their use. Remote sensing methods, techniques, and equipment are developing so fast preservationists often cannot keep up. * This is a disadvantage for preservation because it is impossible to develop technical or methodological standards when hardware and software formats change rapidly.

Because of the utility of remote sensing techniques, a vigorous government program (perhaps within the Department of the Interior) to assist archaeologists and other preservation professionals in using remote sensing techniques may be appropriate. Recently, NASA provided training in remote sensing methods to several archaeologists through its Earth Resources Laboratories in Bay St. Louis, Mississippi. Such a program might serve as a model for other Federal efforts.

During the 1970s, the National park Service within its Southwest Regional Office developed a research program that successfully demonstrated the utility of remote sensing techniques for managing cultural resources. That office has published a series of reports of high utility for understanding and applying remote sensing technologies. However, in recent years, the staff and funding of that office have been reduced and its research activities have dwindled.

Predictive Modeling

Predictive locational modeling is the general term used for a group of techniques used to predict the distribution of archaeologically significant material in a region. Not only is it potentially useful for finding sites, it can be an integral part of the scientific explanation of archaeological remains.

Although such techniques are significant both for research and for cultural resource management, misconceptions about them abound among archaeologists and cultural resource managers. They have in some cases been oversold. For example, some thought it would be possible to use remote sensing and other methods to survey an area, find all the sites, and assess their relative significance. This has not proved to be the case. Sites have been missed, and their significance not appreciated.[34] With considerably more research,

[32]Such research institutions as the Center for Remote sensing at Boston University, and the Center for Earth Observations and Remote Sensing at the University of Colorado, can be expected to enhance the transfer of remote sensing techniques into preservation.

[33]Andrew Lippman, "Movie-Maps: An Application of the Optical Videodisc to Computer Graph ics," *Proceedings of SIGGRAPH '80: Seventh Annual Conference on Computer Graphics and Interactive Techniques,* Seattle, WA, July 14-18, 1980.

*For example, instead of detecting 10 to 15 shades of grey in the visible part of the spectrum from black and white photography, digital remotely sensed data allow discrimination among 256 shades in a variety of spectral bands, including the infrared. Processing this enormous amount of data requires a large computer that can quickly and efficiently process large amounts of information.

[34]See the various articles in Jim Judge and Lynn Sebastian, *Cultural Resource Predictive Modeling,* Report of Bureau of Land Management, Denver Service Center, Denver, CO (in draft). This document is an attempt to bring together the theory and practice of predictive modeling in one place.

predictive locational modeling will likely be a powerful tool for management as well as research. Improvements in the techniques are of particular importance because it could give better control over the resource base which is being destroyed at an alarming rate by both environmental and human factors.

Archaeologists use two distinct families of approaches. One is an empirical, or inferential, approach that attempts to extrapolate from known distributions within a surveyed sample of a region to unsurveyed areas. The other, which is complementary, is a theoretical, or deductive, approach that is based on underlying assumptions about how people might have behaved, given a particular paleolandscape (e.g., climate, soil productivity, landform characteristics, availability of game) .[35]

Although the empirical, correlational models work to a certain level, they do not explain why people behaved as they did in the past. Deductive models, on the other hand, explain why people behaved as we observe, but they have not been widely applied because they are more difficult to develop. Thus their potential accuracy is uncertain.

Many archaeologists and historians have expressed severe reservations about how effective predictive modeling might be as a management tool and fear that it might be misused in an effort to avoid costly ground surveyor detailed archival research. The models are not likely to tell us where all the sites are because it is unlikely that human behavior can be determined to that degree. Because human behavior is responsive both to predictable needs and essentially unpredictable historical circumstances, even highly sophisticated locational models cannot be expected to be completely accurate.

Their use for locating sites implies a set of assumptions (i e., a model) about how the culture under study works. A model that incorporates too few parameters may lead to incorrect results. Sites are just one part of an entire cultural system that includes intellectual (e.g., philosophy and theology) as well as material determinants. Predicting locations of sites without considering the entire organizational system (as much as can be known) of the prehistoric society will lead to incorrect results.[36] Societies include not only living and working areas, but such elements as planning, division of labor, and mobility, among others. in addition, many have expressed the concern that models may help in locating typical sites, but may be totally useless in locating atypicalones.[37] Adequate protection of historic and prehistoric properties requires unique as well as typical sites be identified and protected.

From a management perspective, it is the anomalies that may be important because they draw the attention of the public and are likely to suffer most from visitation. For example, Stonehenge is celebrated throughout literature i n part because it is unique. Yet there are thousands of smaller and less famous stone circles throughout the British Isles. The latter provide more information about prehistoric culture than does Stonehenge. In the United States, the Serpent Mound in central Ohio is a remarkable prehistoric landform that often serves as an illustrative example of the accomplishments of the prehistoric Indians who constructed the mounds. However, it too is exceptional among the thousands of mounds in the Central United States.

From the standpoint of predictive modeling, the anomalies may not be so important. For example, ordinary trash is of less interest to the lay person than the trash of a celebrity, but of greater interest to the archaeologist or historian attempting to understand how the average person lives. Nevertheless, because of this and related concerns, several participants noted that predictive modeling may not result in great cost savings. It may provide other benefits, including better land-use planning and better understanding of now

[35]William C. Smith and James C. Chatters, "Archaeological Predictive Modeling: The Yakima Firing Center, " Central Washington Archaeological Survey and Geographic ınformation Systems Laboratory, Central Washington University, Ellensburg, WA, March 1986.

[36]For example, like trying to predict the patterns of telephone usage in a city, taking into account only the residential usage.

[37]For example, we may learn that a given cu ltu re prefers settling within a certain distance from a stream bed and are able successfully to predict sites on that basis, However, such a model would not necessarily allow for a variety of special-purpose sites, or for the case of a community from the same culture that decided to break with tradition because of political differences and settled much farther away.

extinct subsistence and settlement systems. Finally, it may find its greatest utility as a guide to field sampling.

One of the big problems for developing predictive locational models is the difficulty in comparing data generated by one archaeologist with data from another. Neither predictive locational models nor the way basic field data are accumulated exhibit very much standardization.

in using remote sensing or predictive modeling, it is essential to define the research problem because preliminary evaluation often constitutes the basis for research and later interpretation and preservation.[38] A search of archival materials is extremely important.

Identification and Survey of Submerged Cultural Resources

Because many of the technologies used for survey and identification of submerged cultural resources are unique to underwater archaeology, they are treated separately in this section. A variety of techniques are used to locate underwater sites. The simplest techniques mimic those used on land and include random searches as well as controlled coverage by scuba[39] divers positioned at regular intervals along swimlines. Although simple approaches and accidental finds have

[38] For example, **Site-** landform correlations. Some types Of environmental considerations and some cultural patterns change the landscape in identifiable, systematic ways. Seeing where sites cluster in one part of the region can provide one with guidelines for sampling elsewhere.

[39] Self Contained Underwater Breathing Apparatus.

Point Reyes Nationai Seashore

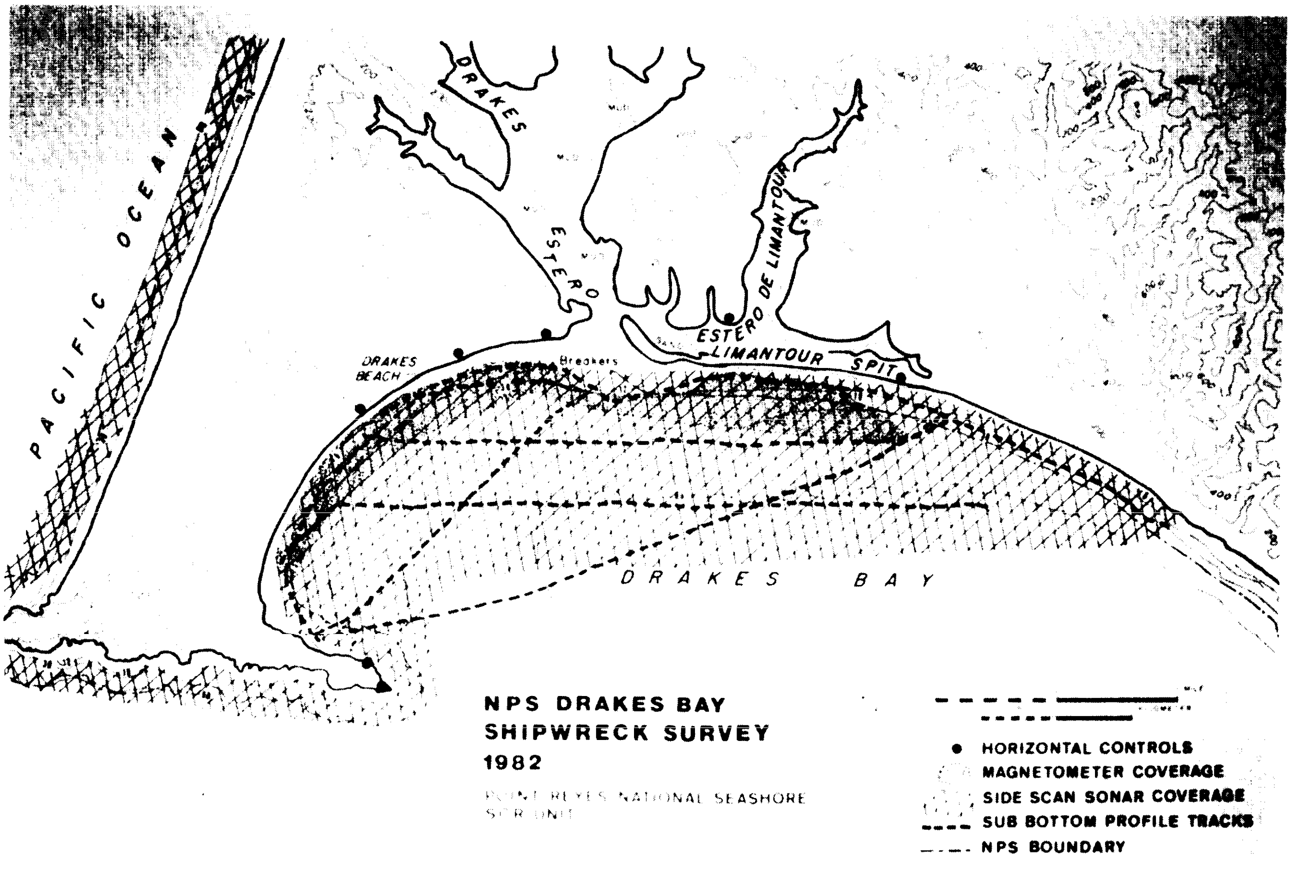

Photo credit: Submerged Cultural Resources Unit (SCRU), National Park Service

This map illustrates the degree of overlap between the various remote sensing equipment profiles employed to cover a particular area at Point Reyes National Seashore during a 1983 survey.

yielded some significant discoveries, most are haphazard and unpredictable.

The most promising, efficient, and accurate approaches to resource location rely on nondestructive, electronic remote sensing technologies. Underwater remote sensing surveys are conducted in compliance with environmental regulations prior to activities such as dredging or offshore mineral development that would disturb or destroy sites. These surveys employ a variety of instruments including magnetometers, sub-bottom profilers, side-scan sonar, precision fathometers, and electronic positioners. Refinements and advances in sub-bottom profiling, and side-scan sonar[40] have been driven, primarily, by the demands of the military and the gas and petroleum industries. Until these technologies were incorporated into underwater archaeology, quick and accurate large-area surveys of the ocean floor were virtually impossible to carry out.

Surveys made with these remote sensing methods result in electronic records, patterns of images or signals in either analog strip charts or digital records. These images indicate both normal and anomalous bottom and sub-bottom phenomena. As in land archaeology, the sources of anomalous signals can only be identified as archaeological material through examination *in situ.* It is important for underwater archaeologists to continue building a "catalog" of representative signals matched with specific anomalous image sources to examine and test new underwater contexts such as estuaries and deep water more effectively and efficiently.

- *Side-sea n sonar sends* out acoustic pulses from an instrument located below a survey ship. A receiver on the ship detects the reflected signal and creates an image of the ocean floor based on the return time and direction of each reflected signal. It produces excellent images of the topography of the ocean floor, including structures and shipwrecks; it cannot detect materials covered by sediments. Unlike sub-bottom profiling, side-scan sonar can cover wide areas of the ocean bed, enabling the quick and accurate mapping of such geological phenomena as drowned river systems.
- *Sub-bottom profiers*[41] are sonar instruments that generate acoustical pulses downward. These pulses in turn are reflected back from sediment layers below the ocean floor. Each layer produces a discrete echo that is received and printed on strip charts. The range of images approximate to a high degree of resolution (less than a meter) the sub-bottom levels encountered. Sub-bottom profilers were designed for use in deep water and,

Side"Scan Sonar Unit

Photo credit: ***National Oceanic*** *and Atmospheric Administration*

The side-scan sonar unit is being lowered into the water at the *U.S.S. Monitor site,* **off Cape Hatteras, NC.**

[40] C.J. Ingram, "High-Resolution Side Scan Sonar/Subbottom Profiling to 6,000 Mile Water Depth, " paper presented at the Pacific Congress on Marine Technology, Hawaii, Mar. 24-28, 1986.

[41] Milton B. Dobrin, *Introduction to Geophysical Prospecting* (New York: McGraw-Hill, 1976).

Photo credit: Garry Kozak, Klein Associates

Side-scan sonar of the *The At/antic,* **a wooden, side-wheel U.S. steamship sunk in 1852, in the Canadian waters of Lake Erie. The ship rests nearly upright, 160 feet below the surface. Because it lies in cold, freshwater, it is remarkably well-preserved.**

until recently, were not well suited for use in shallow water. However, modifications now enable them to operate in less than 6 m of water. They are limited to surveying only the area directly beneath their vessels and, thus, must make many closely spaced sweeps over large survey tracts.

- *Magnetometers*[42] sense the magnetic field anomalies created by ferrous materials on the ocean floor. Therefore they can only locate shipwrecks and other historic sites containing such metals. Their major shortcoming is that they must be relatively close to their targets because the targets' magnetic fields attenuate rapidly (by the inverse square) as the distance between them and magnetometric sensors increases. Magnetometers cannot easily trace weak signals or anomalies, such as those detected from under sediments, to their sources. Greater use of airborne magnetometry could lead to faster, broader, and more accurate coverage within survey perimeters. Even remote sensing from space as it is refined to more deeply penetrate the water's surface could soon be applied to underwater archaeological site identification and management, as it has been to hydrography .43
- *Remotely operated vehicles (ROVs):* ROVs have been undergoing rapid change and development, going deeper to bring clearer pictures than ever before of the seabed. De-

[42] Ibid.

[43] J. Barto Arnold, III, "Remote Sensing in Archaeology, " *The International Journal of Nautical Archaeology and Underwater Exploration,* 1981.

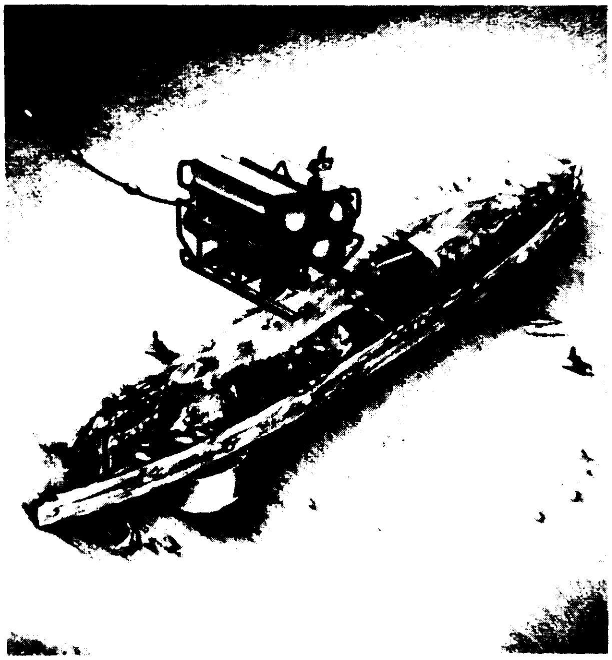

Photo *credit: Eastport, International*

Artist's rendering of a remotely operated vehicle, DEEP DRONE, which hovers over *U.S.S. Monitor,* lying 230 feet deep off the coast of Cape Hatteras, NC

veloped in response to the needs of the military and oil, gas, and minerals exploration companies, they are replacing human divers in a great many underwater tasks. They can remain submerged for weeks to survey huge areas of the ocean floor.

For example, the historic discovery of the wreck *Titanic*[44] in April 1985, was achieved through an unmanned craft, the *Argo,* tethered to a ship by 13,000 feet of cable. Outfitted with television cameras, high-powered lights, and sonar scanners, it revealed new information about an environment that had previously been closed to archaeological research. The *Titanic* was later explored by a manned vehicle, the *Alvin,* and a remotely operated craft, Jason, Jr. in an attempt to gather photographic and other data on the wreck's condition.[45]

[44] Robert D. Ballard, "How We Found the *Titanic,* " *National Geographic* 168, 1985, pp. 696-722,

[45] Walter Sullivan, "Manned Sub Descends To View the Titanic, " New *York Times,* July 15, 1986, p. Cl.

DOCUMENTATION AND ANALYSIS

Documentation and analysis are the heart of the research process. It is here that a research plan, or design, is particularly important, because excavation, coring, test trenches, and dismantling the outer layers of an historic structure may destroy some or all of the resource. Techniques that provide nondestructive, objective ways of documenting cultural resources are extremely important, because the primary way for others to judge the quality of the analytical results is to examine the original data. It is therefore especially important that the data be as free of the investigator's bias as possible, and that data recovery methods be designed to answer a wide variety of potential research questions.[46]

[46] See Allan E. Kane, William D. Lipe, Ruthann Knudson, Timothy A. Kohler, Steven E. James, Patrick Hogan, and Lynne Sebastian, "The Dolores Archaeological Program Research Design, " *Dolores Archaeological Program: Field Investigations and Analysis—1978* (Denver, CO: Engineering and Research Center, Bureau of Reclamation, U.S. Department of the Interior, November 1983) for a detailed view of a wide-ranging research design.

In many cases, new techniques and methods have made possible the collection or interpretation of data far beyond what was possible just a few years ago. For example, in the excavation of the prehistoric Koster Site in west-central Illinois,[47] the development of flotation techniques for collecting plant materials, seeds, and pollen led to a much better appreciation of the complexity of the prehistoric Indian societies that inhabited the site over the centuries and their ability to adapt to new conditions.

Refinements in radiocarbon dating have made possible the determination of more accurate dates for historic structures and landscapes as well as prehistoric sites. Archaeomagnetic and obsidian hydration dating techniques, developed in the 197os, have restructured our understanding of the dates of certain archaeological sites for which there is no datable wood.

[47] S. Struever and F.A. Holton, *Koster: Americans in Search of Their Prehistoric Past (New* York: Signet, 1979).

Technologies

This section discusses some representative techniques (table 7) used by archaeologists and historians to analyze prehistoric and historic cultural resources. The technologies discussed are illustrative and not intended to be inclusive.

Excavation

Site Sampling and Evaluation.–As archaeologists attempt to tackle ever more sophisticated problems, requiring finer distinctions among sites and groups of sites, the relevance of how they collect materials from a site and where they decide to dig within a site becomes more important.[48] Site sampling and evaluation techniques allow the archaeologist to determine: 1) which sites to excavate, 2) whereto excavate within the site, 3) where the site boundaries are, and 4) how to collect materials from within each site. For example, in excavating Pueblo Alto, a major prehistoric Chaco Canyon village, in the late 197os, only 10 percent of the structure was actually excavated. National Park Service archaeologists used sampling techniques to decide where to dig, and saved most of the structure for future research .[49]

Sampling makes extensive use of magnetometers, soil resistivity methods, subsurface radar, and other remote sensing technologies also employed for survey and identification, to find remnants of structures, and other evidence of human activity.

Archaeologists and landscape architects also employ coring techniques to sample the earth for evidence of human activity. Refinements in these techniques for other purposes will benefit the sampling process. [so]

[48] Timothy A, Kohler, Carl J. Phagan, and Eric Blinman, ''Sources of Confounding Variability in Archaeological Collections, " Dolores Archaeological Program Technical Report Number DAP-282, Dec. 4, 1982.

Table 7.—Technologies for Gathering and Analyzing Data

Excavation:
Coring tools
Probing tools
Digging tools
Screens
Sifters
Sorters
Flotation techniques
Sample collection devices
Site sampling devices
Portable generators
Soil micromorphology
Soil profile techniques (interpreting and recording)
Temporary shelters over sites during excavation
Inspection:
Visual
X-ray
Infrared
Moisture meters
Neutron/gamma-ray spectroscopy
Documentation:
Computers
Bar code generators
Drawings
Photographic cameras
Video cameras
Analysis:
Computers
Geographic Information Systems
Chemical

SOURCE' Office of Technology Assessment.

Inspection

Neutron/Gamma-Ray Spectroscopy .-A promising new technology, developed originally to analyze the chemical composition of lunar soil, makes use of neutron/gamma-ray spectroscopy. The technique makes use of a radioactive source (californium 252) that emits high-energy neutrons. Because of their high energy, neutrons may travel as much as several meters, depending on the type of material they penetrate. In using the technique, the experimenter places the neutron source against the material to be analyzed, and the resulting neutrons pass through it, striking atoms of various elements within. The atoms emit gamma rays (high-energy electromagnetic waves) characteristic of the atom struck. A gamma-ray detector on the other side of the material determines the intensity and energy of the gamma-rays so emitted. Analysis of the spectrum of these gamma rays allows the experimenter to determine the chemical composition of the material between the neutron source and the gamma-ray detector.

[49] James judge, Southern Methodist University, personal communication, 1985.

[50] See Julie K. Stein, "Coring Archaeological Sites, " *American Antiquity,* 1986, **pp.** 505-527, for a discussion of coring technology and history of its use.

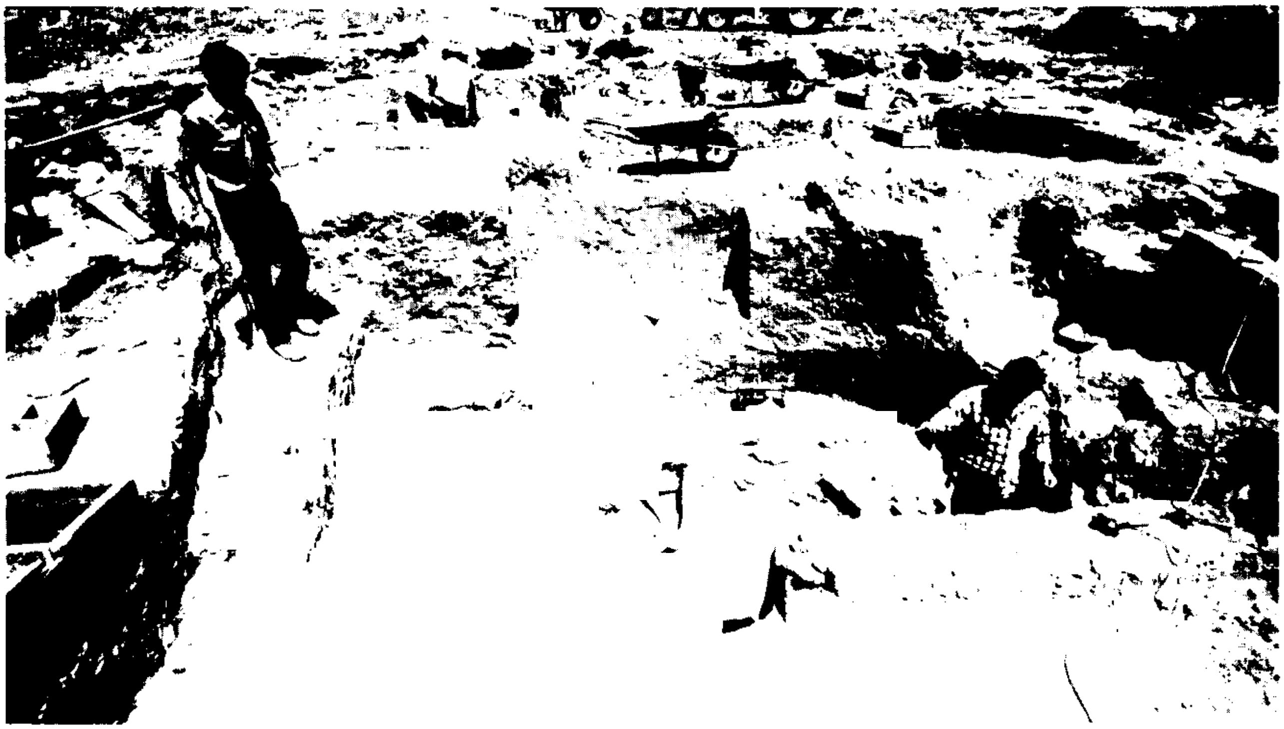

Photo credit: Ray A. Wi///amson

National Park Service archaeologists excavating pithouse remains in Chaco Canyon National Historical Park, NM.

This nondestructive technology, recently "transferred" to preservation has been successfully field tested on historic structures at Colonial Williamsburg, Virginia, and in Venice, Italy. The deep-penetrating technology enables scientists to determine the kind, distribution, and amount of contaminants within structural materials. Such contaminants may result in the destruction of the material. For example, in an investigation of a smokehouse in Williamsburg, the technique was used to determine the concentration of damaging salts in the smokehouse roof. The technique could also be used to monitor the effectiveness of stone consolidation. It constitutes a significant advance over previous techniques, such as core sample analysis, which is destructive; electrical conductivity, which measures only surface moisture and is affected by salts; and neutron thermalization, which is limited to shallow surface diagnosis.[51]

Infrared, Ultraviolet, and X-ray Inspection.– Such techniques, which make use of analytical methods depending on wavelengths of light beyond the visible range for humans, have greatly expanded the ability of architects to determine the original colors of paint, or to "see" features otherwise invisible to the naked eye. For example, by using ultraviolet light, architects examining Gunston Hall in Virginia, were able to determine that many of the carved wooden decorations originally on the interior walls had been removed at some time in the past.[52] Even high-intensity visible light may reveal details or "ghost" images and contours that are invisible in normal illumination.

X-ray analysis makes possible the inspection of features hidden from view behind structural materials, or even within a structure. For example, it has been used to reveal the presence of hand-wrought nails connecting balusters to a handrail, confirming that the staircase was original 18th

51 L.G. Evans,). I Trombka, R.A. Livingston, and T.H. Taylor, "Neutron/Gamma-Ray Techniques for Investigating the Deterioration of Historic Build ings, " *Nuclear Instruments and Methods in Physics Research A242* (Amsterdam: North Holland, 1986).

52 Thomas J. Colin, "Solving the Mystery of Gunston Hall, " *Historic Preservation*, June 1984, pp. 40-45.

century construction, and not a restoration.[53] Portable, relatively inexpensive units, make field inspection practical in a variety of conditions. X-rays can penetrate most common building materials, but to varying depths. Conventional plaster and wood are most easily penetrated; most metals, masonry, and earth absorb X-rays easily.

In practice, the)(-ray unit is set upon one side of the construction medium under study. A film pack containing a specially coated screen which fluoresces when struck by X-rays, contains high-speed photographic film, which is exposed by the fluorescent screen. By using Polaroid film in the film pack, the structural analyst can see results immediately and, if necessary, reposition the apparatus to produce the desired results.

In 1981, X-ray analysis revealed the answer to long-standing questions regarding details on the internal structure of the dome of Thomas Jefferson's Virginia home, Monticello, whether it was, in fact constructed "in Delorme's manner." The evidence was found in Jefferson's personal notebook on dome design and remodeling the property. That document indicates that Jefferson intended, in constructing the dome of Monticello, to incorporate techniques he learned during his tenure as American Minister to France. Developed by Philibert Delorme, a 16th century architect in the French court, the approach employed wooden planks laminated in short, curved segments to form long, continuous structural ribs that could then be used to vault arched spaces. This technique represented an improvement over traditional timber vaulting methods in that it was lightweight, inexpensive, and easily and quickly assembled.

In the absence of more detailed notes and drawings, and because destructive analytical devices are inappropriate for such an architecturally and historically significant building, X-ray examination proved ideal for penetrating the dome's surfaces. X-ray techniques confirmed the degree to which Jefferson varied his application of Delorme's technique.[54] Important findings include the use in Monticello's dome of four laminations per rib rather than the two per rib of Delorme. In addition, Monticello's dome features wrought nails and spikes instead of mortises, tenons, and pegs for attaching structural elements. X-ray technology showed clearly the innovation behind Jefferson's adaptation.

Chemical and Physical Analysis

A variety of methods are used to determine the chemical constituents and physical properties of paint, wallpaper, and materials incorporated within historic structures. Most involve the laboratory analysis of samples removed from a historic structure. For example, in examining fragments of wallpaper used at different times in Gunston Hall, researchers have analyzed six different wallpapers and found that each of them contained wood pulp, which indicated that they all dated from later than 1825, as earlier paper was made from rags.[55]

[53] See David McLaren Hart, "X-Ray Inspection Of Historic Structures: An Aid To Dating and Structural Analyses, " *Technology & Conservation,* summer 1977, pp. 10-27, for a comprehensive summary of X-ray techniques.

[54] Douglas Harnsberger, "In Delorme's Manner, " *APT Bulletin,* vol. XII, No, 4, 1981.

[55] Ibid.

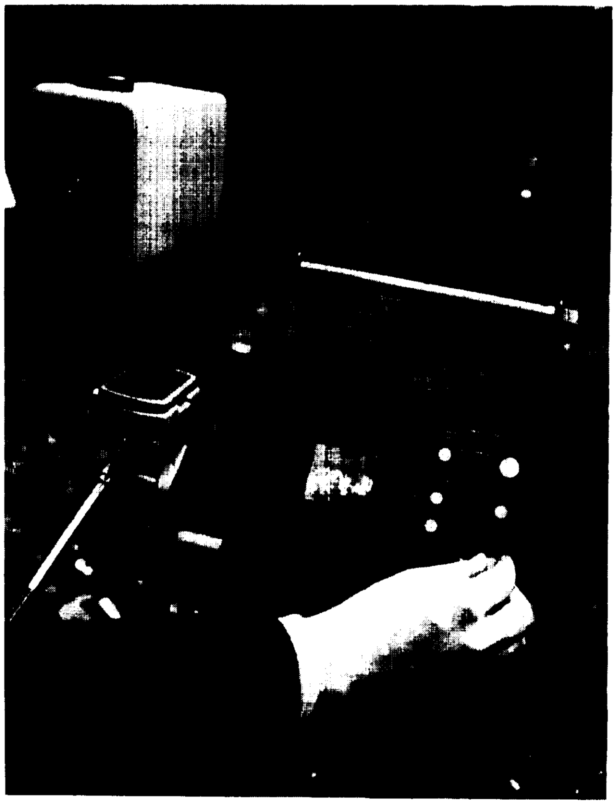

Photo credlt: Preservatlon Assistance Division, National Park Service

Infrared Moisture Detection, Rome. Demonstration of remotely operated unit.

Chemical analysis of stone can aid in determining the quarry from which it was mined. Chemical analysis of wood can aid in determining whether structural and decorative or applied wood is part of the original fabric or newer and, therefore a replacement or addition.

However, proper diagnosis of the condition of historic structures begins with visual inspection, as exterior signs of decay and degradation in buildings are often obvious. The senses of smell and touch and hearing also identify deterioration. Musty odors and damp surfaces suggest the presence of damaging levels of moisture; certain sounds can indicate whether or not a structural member is firm or weakened. Examination of the soundness of roofing systems reveals much about possible water damage.[56] Tables 8 through 11 present a variety of diagnostic tests that can be used in examining damage to wood, masonry, iron and steel, an-d reinforced concrete.

Information Analysis

Computerized Geographic Information Systems.–Geographic Information Systems (G IS) are

[5] **Worrest** Wilson, "Building Diagnostics, " *Architectural Technology*, winter 1985.

Table 8.—Technologies for Analyzing the Physical Condition of Wood

Diagnose	Test method	+Advantages – Disadvantages
Decay, species	Visual	+good preliminary step –other tests should follow to determine internal conditions, stability
Strength and grade	Visual	+Well-suited for grading inspection +gives a measure of structural adequacy –limited to accessibility, may be impractical if grade marks painted over
Density, strength, degree of degradation	Manual probing	+good to detect surface decay +fast, easy to identify advanced decay –other tests needed to assess internal quality –not all surfaces may be accessible –cannot detect internal decay
Moisture content	Dielectric moisture meters, power-loss meter	+easy to use, will not upset surface –limited range: 0°/0 to 39% moisture content –sensitive principally to surface of sample –accuracy impaired when moisture gradient present – reading affected by specimen density, chemical treatments or decay
	Resistance-type moisture meter	+ meter simple, rugged; readout in direct units +calibrations for grades and species –limited range: 7°/0 to 30°/0 moisture content –data influenced by some preservatives, fire retardants and decay
	Electrical resistance probe	+measures changes in long-term moisture content remotely +can be built into structure – used only in research –limited range: 7°/0 to 35°/0 moisture content
Strength, modulus of elasticity	Ultrasonic, pulse velocity	+equipment portable, fast, and readily adaptable for field use –affected by wood characteristics that are not flaws, such as moisture content
	Stress-wave propagation	+portable, light, inexpensive –requires trained personnel
Moisture content	Weight test, oven-drying	+accurate at any level of moisture content –takes time, requires lab test-equipment
Grain direction, irregularities, decay, splits, knots, moisture content, insect damage, location and size of members	Radiographic	+provides permanent record +equipment light, portable, easy to use –radiation is unhealthy, requires shielding –initial cost high –field development not complete –specimen must be accessible on both sides

SOURCE: Forrest Wilson, "Building Diagnostics" *Architectural Technology,* winter 1985; Neal Fitzsimmons; U.S. Department of Housing and Urban Development.

Table 9.—Technologies for Anaiyzing the Physicai Condition of Masonry

Diagnose	Test method	+Advantages – Disadvantages
Flexural bond strength	Load testing	+ accurate –destructive
Shear strength or diagonal strength	Load testing	+ accurate –destructive
Water absorption	Weighing, dry and saturated	+accurate –time-consuming
Size	Visual measurement	+fast, requires little skill –will not determine strength or durability
Warpage	Visual inspection	+fast, requires little skill –will not determine strength or durability
Imperviousness	Ink test	+fast –will not determine strength or durability
Chemical resistance	Acid dripping	+useful if exposure to certain chemicals is anticipated –will not determine strength or durability
Crazing	Autoclave test	+reliable test –safety precautions required –will not determine strength or durability
Leakage, water permeance	Spray test	+ rate of leakage and water permeance be observed + used for comparison of masonry specimen; simple modifications make useful for in-situ testing –will not determine strength or durability, other than that inferred from porosity
Compressive strength	Masonry prisms	+results reliable if taken from actual building materials – results uncertain if materials different from actual building
Structural soundness, mortar bond, filled cells	Hammer test (light tapping)	+fast approximation – requires skilled tester with good hearing – may require additional testing to validate findings
Inner cell grout, wall thickness	Probe holes	+small holes from test easily patched + requires only semiskilled evaluator –an approximation, requires many drill holes unless combined with fiber optics
Continuity, voids, cracks, estimate of compressive strength	Ultrasonics (low frequency)	+accurate evaluation of several parameters – requires skilled, experienced operators –expensive
Voids and reinforcement	Radiography	+accurate evaluation of parameters; permanent record on film – requires access of both sides of specimen –requires safety precautions; expensive
Location of reinforcement	Tachometer	+requires fast, semiskilled operator +gives locations and depth of reinforcement –used only for light reinforcement; difficult to interpret if both joint and cell reinforcement used.

SOURCE: Forrest Wilson, “Building Diagnostics” *Architectural Technology,* winter 1985; Neal Fitzsimmons; U.S. Department of Housing and Urban Development.

computerized database systems in which the data are explicitly spatial in nature and organization. Such systems can be applied in studies of prehistoric and historic settlement patterns, and to planning for future development.

A complete GIS includes both computer software and hardware. It is capable of merging and analyzing a wide variety of data for their information content and displaying them graphically. A system capable of processing large amounts of information quickly (on minicomputers or mainframe computers) would cost on the order of $50,000 or more, although smaller, less capable systems for microcomputers (such as P-MAP, and RIPS) are available at much lower costs. Examples of the more extensive systems, in the public domain, include MOSS/MAPS (Bureau of Land Management), Geographical Resources Analysis Support System (GRASS)[57] (under development by the Construction Engineering Research Laboratory of the Army Corps of Engineers), and SAGIS (National Park Service).[58]

[57] J. Westervelt, W. Goran, and M. Shapiro, “Development and Applications of Grass: The Geographical Resources Analysis Support System,” manuscript, U.S. Army Construction Engineering Research Laboratory, Champaign.

[58] Remotely sensed data are ideally suited for analysis by GIS.

Table 10.—Technologies for Analyzing the Physical Condition of Reinforced Concrete

Diagnose	Test method	+Advantages –Disadvantages
Surface flaws	Visual, optical	+ inexpensive + no special equipment needed + reveals defects other methods won't –provides information on surface only
Differential movements over time	Surveying	+ provides cyclical relationships between deformation, temperature and load – immediate interpretations not available –trained surveyor required
Joint survey, expansion, contraction, cracking, variety of conditions	Visual joint inspection	+ inexpensive initial first step in a more in-depth investigation + most applicable to foundations, walls, slabs –trained observer required for data collection and evaluation
Internal cracks, voids, flaws	Fiber optics visual survey	+yields clear, high-resolution image of remote inspection areas –requires path to surface; may require multiple boreholes
Surface hardness—relative quality of concrete	Rebound hammer	+ inexpensive, fast; can be used by inexperienced personnel – indications of strength not accurate – results affected by condition of concrete surface – requires correlation between rebound value and concrete
Compressive strength	Penetration, Windsor probe	+equipment is simple, durable +field operation requires minimum training –accuracy depends on location of test and accuracy of depth gauge –slightly damages small area of concrete – provides accurate strength determination only with correlation of depth of penetration and concrete strength
Moisture content	Dielectric	+equipment readily automated – used in the past only in laboratories – accuracy of 25°/0 –equipment very expensive, tests only for moisture content
Slab thickness, re-bar location	Electrical resistivity	+ equipment easy to use –limited to pavements and on-grade slabs – results inaccurate, affected by air entrainment density, moisture, salt content, and temperature gradients
Locate ferromagnetic elements, location and depth	Magnetic cover meters, Tachometers	+light, portable, easy to operate, inexpensive –battery equipment will not operate satisfactorily below 32° F –good results only with one layer of re-bar –will not work well with mesh
Growing internal flaws	Acoustic emission, stress waves	+equipment simple, easy to operate +data gathering requires minimal training –data interpretation requires an expert –background noise distorts results –computer recommended for triangulation of flaw location – used only when structure is loaded and flaws increasing

SOURCE' Forrest Wilson, "Building Diagnostics" *Architectural Technology*, winter 1985, Neal Fitzsimmons; U.S. Department of Housing and Urban Development

Table II.—Technologies for Analyzing the Physical Condition of Iron and Steel

Diagnose	Test method	+Advantages – Disadvantages
Surface characteristics, flaws, corrosion, pits, etc.	visual, optical, horoscopes, fiber-optic, etc.	+ permits inspection of surface and hidden surfaces if access available –detect only visible flaws on surface or below surface through access channels
Material separations (open to surface)	Liquid penetrant containing dye	+ permits inspection of complex shapes in a single operation + inexpensive, easy to apply, portable –shows only defects open to the surface – messy, with irrelevant indications – results depend on operator's ability – results must be carefully controlled
Cracks, seams, laps, voids, porosity, and inclusions	Magnetic particle	+simpie, inexpensive +senses flaws down to 1/4 inch as well as surface flaws +not applicable to nonmagnetic metals or materials –messy, careful surface preparation required –irrelevant indications often occur –results depend on operator's skill
Voids, porosity, inclusions, and cracks	X-ray and gamma-ray radiographic	+detects both internal and external flaws + portable + permanent record –expensive; heavy –health hazard, requires shielding –complex shapes difficult to analyze
Surface-finish discontinuities, cracks, seams, variation in alloy composition or heat treatment	Eddy current	+moderate cost; readily automated + portable; permanent record available +can be adapted to comparative analysis – useful on conductive materials only – shallow penetration – reference standards often required – provides only qualitative comparison
Yield strength, yield point, tensile strength, modulus of elasticity, compressive strength	Coupon	+fast, accurate results of physical and mechanical values –destructive to sample removed for testing

SOURCE: Forrest Wilson, "Building Diagnostics" *Architectural Technology,* winter 1985; Neal Fitzsimmons; U.S. Department of Housing and Urban Development.

These systems are available for a wide variety of analytical and management chores because many cultural resource data are spatial in nature, For example, the goal of much archaeological research is to discern patterns in the distribution of artifacts, structures, or other cultural materials across the Earth's surface. GIS can also be used to relate data from different parts of a site at a variety of scales. In archaeology, GIS methods have been used most extensively to predict the occurrence of sites in a given region of interest (predictive locational modeling).

GIS can be especially useful for analyzing landscapes. The Army, for example, has used existing GIS technologies to map vegetation, slopes, and archaeological sites across a Landscape.[59] The system can plot every known site. Army technicians can even show how the landscape looks at different times of the day or season, Although the Army uses such information for planning military exercises, and other strictly military purposes, some of these techniques could be transferred into the civilian realm.

The expense of the technology, however, has limited its use by archaeologists and landscape architects. **Regional GIS centers, that maintained shared environmental and other databases, would make it possible for these groups to gain access to advanced** GIS **methods and help spread this technological innovation more rapidly and effectively through the preservation community.** Such centers could provide training for archaeologists and others in GIS methods. They are likely to be highly effective within the university com-

[59] Constance Ramieriz, Department of the Army, personal communication, 1986.

munity, where archaeologists and many other professionals using GIS technology can work together on common problems.

Dating Techniques

The development of a series of physical dating techniques (table 12) by physicists and chemists provides one of the best examples of the successful application of technology to archaeology over the last 30 years. [60] The following discusses two of those methods.

Radiocarbon (Carbon-14) Dating.– Developed by W.F. Libby and his co-workers at the University of Chicago just after World War 11, radiocarbon dating is the most widely used and best-known dating method. It relies on the fact that all living organisms contain carbon atoms, an extremely small percentage of which (about one part in a trillion) is the mildly radioactive isotope, carbon-1 4. While the organism is still living, the percentage of carbon-14 is maintained in equilibrium through exchange with atmospheric carbon. However, when it dies, no further exchange is possible and the carbon-14 decays slowly (with a half-life of about 6,000 years).

This technique is capable of providing ages of organic materials for the last 30,000 to 70,000 years (depending on the size of the sample and the experimental conditions). For periods of 5,000 years or less, and sample sizes of a gram or more,[61] the technique can determine the age of a sample with a typical precision of +/-20 to +/-150 years. However, the use of radiocarbon techniques for the more recent past (1 7th to 20th century), for example to distinguish renovations from original construction, requires special techniques. Both natural and anthropogenic factors that have affected the ratios of ^{14}C to ^{12}C make unambiguous dating for this time period particularly difficult.

Beginning in the late 1970s, the use of particle accelerators [62] have made possible what is called direct, or ion, counting (as opposed to the conventional decay counting) permitting reductions in the size of the sample required for age determination of factors of 1,000 to 1 million.[63] This improvement makes possible the dating of extremely small samples that were impossible to date several years ago. It also pushes back the epoch for which carbon dating is possible by several thousand years. It might even make possible the dating of European Paleolithic cave paintings or prehistoric American pictographs painted with organic pigment. However, this dating method also means that archaeologists must institute new methods to prevent contamination by historic materials (for instance, by packaging materials).

[60] See Joseph W. Michels, *Dating Methods in Archaeology* (New York: Seminar Press, 1973) for a general discussion of dating methods.

[61] Although a gram of material seems small, some fragments of wood or other organic samples are a gram or smaller. Dating them would therefore destroy them completely.

[62] See, for example, Christopher Chippendale, "Radiocarbon Comes of Age at Oxford," New Scientist, July 21, 1983, pp. 181-184.

[63] Decay counting methods typically require samples of a gram or more of carbon. The newer methods require only micrograms to milligrams of carbon.

Table 12.—Dating Prehistoric Sites

Method	Materials	Range of time
Dendrochronology	Wood	O to 7,000 years
Radiocarbon	Organic materials (wood, seeds, bones, shells)	O to 50,000 years
Archaeomagnetic	Ferrous-bearing material, heated in the past (clay, stone firehearths)	O to 10,000 years
Obsidian hydration	Obsidian	O to 10,000 years
Thermoluminescence	Ceramics, burned rocks, stalagmites	O to hundreds of thousands of years
Fission tracks	Volcanic glass, minerals rich in uranium	O to several hundreds of thousands of years
Potassium-argon	Volcanic lava	1,000 to 1,000 million years

SOURCES Joseph W. Michels, *Dating Methods in Archaeology (New York*: Seminar Press, 1973); Tony Hackens "How Science Unlocks the Secrets of the Past, " *The Courier,* July 1985, pp. 12-22.

Archaeomagnetic Dating.—Archaeomagnetic dating has been widely applied since the 1970s but is still being perfected. It has been most useful in the American Southwest, where dendrochronology (tree ring dating) can be used for calibration. The method depends on the geophysical fact that Earth's magnetic field changes direction and strength over time. When an iron-bearing stone material (e.g., a fire hearth) is heated sufficiently to release molecules of ferrous materials within the hearth from their rigid molecular alignments, they become free to realign themselves in the local magnetic field. That orientation is fixed as the material cools. Comparison today of the molecules' orientation relative to the current field direction (which is constantly changing) can yield an estimate of the date at which the stone archaeological sample was last fired.

The archaeomagnetic scientist maps a set of magnetic pole positions over time based on samples of known ages. The unknown sample is then related to this set. The accuracy of the dates therefore depends on: 1) the rate of the magnetic changes through time—the faster the change, the more accurate the date that results from the comparison; and 2) how well one can collect and measure the orientation of the remnant magnetism in the sample. Recently, the process has become more sophisticated, and at the same time archaeologists have become more rigorous in their use of archaeomagnetic results.

Because archaeomagnetic dating requires independently derived master curves of change of Earth's magnetic field over time, the technique cannot be applied to regions that have no existing master curves. Therefore, every effort should be made to collect samples in these areas so master curves can be developed. Unfortunately, many archaeologists in areas lacking master archaeomagnetic curves are not attuned to the potential of these samples, and because such samples will not help them immediately in dating their sites, they tend not to collect them. However, if support were made available to collect such samples, it would be possible to develop a national archaeomagnetism database.

Archaeomagnetic dating techniques are a direct outgrowth of the interests of geophysicists in the magnetic history of the Earth. In archaeomagnetism, samples collected for archaeology are useful to geophysicists trying to understand the long-term behavior of Earth's magnetic field.

Soil Sciences, Sedimentology, and Geomorphology.–The set of techniques derived from soil science, sedimentology, and geomorphology have been recognized and applied by archaeologists for decades. Until recently, however, such techniques have been invoked primarily to reconstruct likely paleo-environments, Earth sciences have been used to explain the unique proliferation of early people sites in East and South Africa, the movements of Pleistocene hunter-gatherers in glacial Europe, and the conditions favorable to the emergence of agriculture in the Near East and Mesoamerica.

More recent interests in processes of site formation have expanded the domain of inquiry and methodologies to the point where they can identify and often date modes of site occupation, abandonment, and burial. Although such techniques need a great deal of further research, scientists can also explain what environmental processes cause certain sites to maintain integrity despite weathering and the ravages of time. In archaeologically rich areas, distinctive landforms and soil layers identifiable by texture and color, as well as soil chemistry, may serve as regional benchmarks for locating the surfaces of sites, isolating unique environments favored by particular ancient cultures, and for marking occupation sequences over time.

Such methods, applied to understanding the prehistoric case, may provide important data for modern soil problems. For example, study of soil productivity and soil salinity in ancient Mesopotamia may suggest techniques to apply for today's problems of increasing soil salinity in western irrigated soils.[64]

The earth sciences have much to contribute to the preservation and management of cultural resources, in part because they involve study of the interaction of natural and cultural resources. Because of this management potential, for exam-

[64] Diane E, Gel burd, "Managing Salinity: Lessons From the Past," *Journal of Soil and Water Conservation* 40:329-331, *1985.*

ple in locating archaeological sites,[65] an appreciation of the benefits and liabilities of earth science research is especially critical to Federal or State managers of cultural resources. In particular, the National Park Service and the U.S. Army Corps of Engineers recognize the potential of geomorphology and soil science as integral components of large-scale research design. In the future it will be important to focus on the potential of the specialized approaches to particular archaeological problems, such as soils sciences, in the interests of maximizing overall research yield, boosting efficiency, and addressing preservation issues in a systematic manner.

It will also be important to characterize more completely the chemical constituents and chemical interactions of artifacts, structures, and archaeological sediments.

Technologies for Underwater Archaeology

Individuals exploring the sea bottom have a wide array of technologies at their disposal. Deep water technologies such as tethered and free roaming remotely operated vehicles (ROVs) and saturation diving are exerting a profound effect on data recovery in underwater archaeology and maritime preservation.

Technical improvements involving the remote detection of submerged cultural sites completely covered by sand and other sediments would significantly aid underwater archaeological research. Refinements in such techniques as magnetometry, which would allow archaeologists to determine which sites to excavate and where to excavate within them, would benefit the entire underwater archaeological process.

Scuba Diving.–Archaeologists make extensive use of scuba diving equipment and techniques for exploring and excavating sites in shallow waters.

Deep Sea Diving.–The use of saturation divers and deep-diving systems to collect samples at depths totally unattainable to conventional divers has been a major technical innovation. Saturation divers are now able to work at extreme depth for prolonged periods. Bottom times are no longer a function of depth, as they are with scuba diving, and each dive can last for many hours instead of minutes. Breathing an atmosphere of mixed helium-oxygen, divers can attain depths of over 1,000 feet, although decompression afterward may require several days. Habitats, lockout submersibles, and tethered deep-diving systems deploy saturation divers to their destinations.

Remotely Operated Vehicles.–ROVs were discussed earlier in the examination of technologies for discovery. However, they have an important

Photo credit: Institute of Nautical Archaeology

A lifting balloon assists underwater archaeologists in raising artifacts.

[65] L. E. Wildesen and Y. T. Witherspoon, "Locating Significant Archaeological Sites by Landform Analysis in Central Oregon," presented at the Northwest Anthropological Conference, April 1985, Ellensburg, WA,

role in gathering data, either using photographic and video techniques, or collecting, samples. Scorpio, a particular type of new ROV[66] is now being equipped with remotely controlled manipulators. New ROVs are now capable of achieving depths of up to 13,oOO feet and are armed with specialized work packages capable of cleaning oil rig platforms and recovering a vast array of objects.[67] The costs of ROVs are extremely high, however (see *Chapter 7: Preservation Policy).*

Underwater Excavation Technologies. -These techniques range from the extremely simple, such as hand-fanning, to the complex, such as controlled blasting, and include the use of blowers, prop wash deflectors, air hammers, and chisels. Excavation required in dark or "black" water can be virtually impossible to carry out, even in relatively calm, shallow water. Specially designed coffer dams such as that being applied at the Yorktown Archaeological park in Yorktown, Virginia,[68] are improving the ability of divers to find their way in heavily silted waters. In Yorktown, excavation of an 18th century shipwreck is carried out within a steel enclosure filled with river water that is clarified by commercial filtration units. Normal visibility in the York River is usually less than 1 foot. The filtration process increases the visibility inside the protective coffer dam to more than 20 feet, A pier connecting the dam to the shore permits ready access to visitors who are encouraged to observe underwater archaeologists working at the site and to familiarize themselves with part of the archaeological research process.

[66] Jonathan B. Tucker, **"submersibles Reach New Depths, "** *High Technology,* **February 1986.**

[67] The University of **New Hampshire owns possibly the** most **advanced** ROV, EAVE-EAST. It **is autonomous and outfitted with five microprocessors to sense data on altitude, depth, obstacles, and power consumption. Research continues to impart greater dexterity of manipulation and better systems for autonomy.**

[68] John D. Broadwater, Division of Historic Landmarks, York, VA, personal communication, 1986.

ISSUES

Archaeology

1. *Excavation is the last resort in archaeological research.*

Although the public generally associates excavation of sites with archaeology, archaeologists today generally consider excavation to be a last resort, primarily because excavation severely disturbs or even destroys a site and prevents later reexamination and reinterpretation. For many archaeological research problems, the examination of surface remains can yield information just as critical for understanding prehistoric society as excavation. In addition, rather than focus on the site per se, archaeologists today generally view their research in terms of regional, rather than site, analysis. They excavate sites in order to investigate hypotheses generated for a regional context, and investigate the climate, the zoology, and botany of a region as well as its geology and geomorphology.

This point of view represents a change from an earlier approach to archaeology.[69] In the first place, not excavating leaves the remains in place for future research as new techniques allow finer and finer levels of analysis. In the second, techniques are continually being developed that can provide information about a site or area without destroying it. In general, **archaeologists need to excavate less and record the sites they do excavate more carefully .70 Not only should they record the positions and kinds of artifacts more carefully, they should record plant and animal remains found in different layers of the soil, as well as soil color and chemical makeup.**

In addition, as archaeologists continue to increase the amount of data recorded and materials saved when excavating, it becomes proportionately more costly to excavate. Therefore technologies that reduce costs are becoming increasingly important.

Nevertheless, excavation is often the only way to gather sufficient information on an ancient culture. Advanced techniques can make the task of

[69] David J. Meltzer, et al. (eds.), *American Archaeology Past and Future* (Washington, DC: Smithsonian Institution Press, 1986), for several articles concerning the changes that have taken place in the practice of archaeology in the United States in the last 50 years.

[70] E Harris, *Principles of Stratigraphy* (London: Academic press, 1979j.

excavation more efficient, more complete, and more objective. Excavation methods have improved over time and are increasingly designed to preserve more of a given site from the destruction resulting from excavation.

2. *Data recording methods should be improved to make them more complete and more objective.*

New methods also allow archaeologists to standardize the process of gathering data so they are less prone to do onsite interpretation that could lead to bias in their final results. Standardization is especially important as other archaeologists cannot replicate the excavation of a given site. Even sites that are similar and located in the same geographical area are unique in many aspects. By contrast, the science of physics or astronomy depends on the scientist's ability to check each other's work by replicating crucial experiments or observations.

Improvements are especially needed in technologies for constructing accurate three-dimensional maps in the field in order to accurately locate artifacts found on a surface or within a room, because the exact placement of an artifact may provide clues as to how it was used.

One simple, relatively inexpensive technique for recording field data is to use bar code generators to produce bar codes in the field for the purpose of characterizing artifacts. The bar code can then be attached to the artifact for identification in the lab.[71] Recording the excavation with photographs or video cameras allows later interpretation in the laboratory.[72] Orthophotographic techniques, which allow recording of an excavation by means of overhead stereo cameras, need to be made cheaper.

3. *Adequate samples should be collected for later analysis.*

Scientific methods for archaeology are now becoming sophisticated enough that it is profitable to collect material such as soils, cores, and profile peels, that might be analyzed later by microtechniques under development today. Some archaeologists have made and stored collections of soils and cores, but this practice appears to be the exception rather than the rule. Nor are such procedures generally taught in field schools today. Here again, archaeologists need to standardize the collection and recording of samples so material from one site may be compared with that from another.

Material from each excavation is unique from a biophysical and biochemical point of view, so the requirements of data collection at a site can become very specific. Archaeologists are well trained in recovering artifacts, but only relatively recently have they begun to turn their attention to the geological, biophysical, biochemical material. They need experience in the relevant discipline to do this. It is otherwise too easy to make mistakes in deciding exactly what to collect and how to collect and process it. With advanced dating techniques such as radiocarbon, thermoluminescence, and obsidian hydration, for example, it is increasingly important to know more about the surrounding biochemical environment, because techniques now in development use much more sensitive equipment that can date much smaller samples than in the past.

4. *Remote sensing and other locational technologies can be used by looters* as well as *professional archaeologists.*

Unfortunately, the same remote sensing technologies that are available for preservation can be used for increased looting of archaeological sites because many of the data (e. g., the Landsat data and most aerial photos) are available to the public. As archaeologists improve their sophistication in remote sensing techniques, so too will those who wish to exploit cultural resources for personal gain.

This is particularly true for shipwrecks, given the currently clouded legal situation vis-a-vis title to submerged cultural resources (see *Chapter* 7: *Technology and Preservation Policy).* As long as salvers and artifact hunters are allowed to recover the contents of shipwrecks in U.S. waters they will employ a variety of advanced technologies for finding shipwrecks and their con-

[71] Bar code readers and generators are now available even for portable lap computers. Lap computers can also be used to record data and for controlling processes in the field.

[72] For example, color video technology, which allows one to see changes in soil color as the excavation takes place may improve the accuracy of interpretation of the site. Three-dimensional holograms for recording excavation information might also improve the excavation process.

tents. At this point, those who would protect these aspects of U.S. cultural history are not generally finding these sites first and therefore cannot protect them. In States where laws against the looting of historic shipwrecks within designated waters are strongly enforced, improved monitoring and surveillance equipment (see *Chapter 4: Restoration, Conservation, Maintenance, and Protection)* would aid underwater archaeologists and cultural resource managers in developing strategies to safeguard shipwreck sites from illegal intrusion.

Underwater Archaeology

1. *underwater archaeology is highly dependent on advanced technology.*

More than any other preservation field, underwater archaeology depends on a wide array of costly techniques and equipment. Underwater archaeologists confront a host of practical problems, even dangers, that their colleagues working on dry land do not. These problems relate to underwater environmental conditions and include breathing, currents, cold, depth, turbidity, and hostile marine animals; they also relate to time limitations on research and the degree to which remains might be buried beneath sediments or concretion.

The available technologies are generally adequate to the preservation tasks but they are often too expensive. In addition, only a small core of professionals experienced in their use is available, Future research should focus on developing more sensitive, low-cost methods and instrumentation, and on exploiting new sources of information.

2. *A research design is extremely important in determining the appropriate technology to apply to the study of underwater cultural resources.*

In part because underwater archaeology is a relatively new subdiscipline of archaeology, some underwater archaeologists have given relatively little attention to developing a detailed research plan, or design. Yet, in the absence of a detailed research design, including plans for curation of excavated materials, the research project may fall short of its investigator's intent. Archaeologists should not excavate unless they can ensure and specify within a research design, that the materials recovered from the marine environment can be properly housed, conserved, and maintained.

As one archaeologist has complained:

> In the real world of shipwreck archaeology, the commitment to excavation is developed before the conceptualization of a significant rationale for doing it. This is understandable in a CRM [cultural resources management] milieu, i.e., some sort of mitigation must be carried out on a site threatened by dredging or other bottom disturbing construction activities. This, however, is actually rarely the case; usually an institutional researcher has obtained money to excavate a shipwreck, then he may or may not develop a comprehensive statement on why he is going to excavate it—but usually not.[73]

Historic Structures

1. *Nondestructive analytical techniques need to be developed for studying historic structures.*

Given the pace of rehabilitation spurred by preservation tax incentives and the sometimes rapid degradation of some materials from air and water-borne pollutants, the need for more powerful, nondestructive analytical techniques for determining the nature, extent, causes, and results of deterioration and failure of materials is critical. Currently, relevant technologies range from relatively simple, inexpensive hand-held moisture meters to sophisticated neutron/gamma-ray detectors.

2. *Knowledge of the behavior of historic building materials is insufficient.*

Even many preservationists, architects, and engineers have a relatively weak grasp of the detailed behavior of historic building materials. Recognition of the need for careful, scientific testing and monitoring of such materials has emerged only recently. The reactions of historic materials exposed to certain environments have been mis-

[73]Daniel J. Lenihan and Larry Murphy, "Considerations for Research Designs in Shipwreck Archaeology," *Underwater Archaeology: The Challenge Before Us, The Proceedings of the Twelfth Conference on Underwater Archaeology,* Gordon P. Watts, Jr. (cd.) (San Marine, CA: Fortran Eight, 1981).

Photo credit: D. Dwornik, U.S. Geological Survey

Exfoliation of gypsum crust. Georgia marble baluster after 75 years of exposure in Washington, DC. The black crust containing gypsum is a result of sulfur dioxide attack on marble.

understood, which has resulted in some serious conservation problems today. Corrosive interactions introduced into the environment through new and not yet fully monitored industrial and chemical processes are compounding these problems,

In addition, many of the Nation's historic buildings erected between the 1880s and early 1940s were the results of intense competition among product manufacturers, architects, and builders, many of whom closely guarded the secrets of their proprietary designs and processes. This was a very active period in building. Because building materials were not generally tested, their strengths and shortcomings were not fully understood. Often, for example, the most easily carved and, therefore, the least durable stones were placed incorrectly at the tops of buildings or within cornices where they became highly vulnerable to weathering. Poor construction methods, inadequate craftsmanship, and general corner-cutting were almost forced by timeframes and budgets. The installation of incompatible materials in close proximity to each other has resulted in serious problems. For example, oxidation both stains and damages masonry in contact with iron, steel, and copper. Also, changes over time in building shapes toward flattened facades and profiles have all but eliminated highly effective moisture-controlling design features such as projecting string and belt courses, pediments, and water tables, "Most systems and products were developed through trial and error. It was an age of exploitation of building materials and systems. Unfortunately, we are left with that legacy."[74]

The National Bureau of Standards' Center for Building Technology is applying some of the most advanced technologies for characterizing the microstructure and the physical, chemical, and mechanical properties of organic, inorganic, and composite building materials. They employ an array of complex instruments (table 13) to determine and measure the mechanisms of the degradation and decay of building materials.

3. *Preliminary research into the physical history of the structure can focus the use of technology.*

Where construction and repair/rehabilitation documentation has been retained, a search of those records can give basic information on which to build a technological testing program. For instance, the names of quarries for the various types of stone in many of the monuments located in the Mall area of Washington, DC, came from construction documents saved by the Army Corps of Engineers and the National Park Service. In a few cases, the specific vein at the quarry could be identified. This information allows

[74] See Baird M. Smith, "Diagnosis of Nonstructural Problems in Historic Masonry Build ings, " *Conservation of Historic Stone Buildings,* Report of the Committee on Conservation of Historic Stone Buildings and Monuments, National Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council (Washington, DC: National Academy Press, 1982), pp. 212-214.

Table 13.—Major Equipment of the National Bureau of Standards' Center for Building Technology

- scanning electron and light microscopes
- X-ray diffractometer
- thermal analyzers
- ultraviolet visible and Fourier transform infrared spectrophotometers
- mechanical testing machines
- environmental cabinets
- accelerated weathering chambers
- gel permeation chromatography
- ion and gas chromatography
- digital data-collection systems
- minicomputers and microcomputers
- image analyzer

SOURCE: Office of Technology Assessment.

managers to use chemical testing much more specifically because the material has been so closely identified before the testing starts.

4. *The sharing of technologies can make more advanced documentation and analysis of historic structures available.*

Gulf Islands National Seashore, for example, has cooperative agreements with many Florida State bureaus to carry out sophisticated examinations on their historic structures.

5. *Historic structures frequently include additions or have lost portions that reflect an ongoing process of use and change.*

Technologies that can help to illuminate that process of development over time by showing where and how changes and additions have been made will help to reveal the richness of social and cultural change. The documentation and analysis of those changes can also be used to communicate the story of the structure to a wider audience through information developments.

6. *Historic structures should be viewed and analyzed in the context of their full setting, rather than as single buildings divorced from their milieu.*

Thus, many of the techniques involved with landscapes (see below) can be applied to structures and sites as well.

Landscapes

The survey of U.S. prehistoric and historic landscapes is still in its infancy. In part as a result of the lack of adequate survey, the constituency for locating and preserving significant historic landscapes has not yet developed fully, though it is growing.[75] An interdisciplinary team approach is needed in which anthropologists, archaeologists, architects, and historians work together with landscape architects in conducting a broad-based survey of American landscapes.[76]

There are three basic steps in identifying historic landscapes:

1. identifying and accessing records of the known resources;
2. identifying previously unidentified historic landscapes; and
3. recording, storing, and augmenting the newly acquired data.

After being identified (see figure 2), the significance of the landscape must be evaluated against criteria developed for the National Register of Historic Places,[77]

Participants in this assessment raised the following issues related to the discovery and analysis of prehistoric and historic landscapes:

1. *Public officials and individuals are often unaware of the value and significance of historic landscapes.*

Traditionally, historic preservationists have worked from the grassroots. They have built local constituencies that have insisted on the value of a given structure or archaeological site and

[75] See, for example, Eleanor M. Peck, Keith Morgan, and Cynthia Zaitzevsky (eds.), *Olmsted in Massachusetts: The Public Legacy* (Brookline, MA: Massachusetts Association for Olmsted Parks, 1983), for an example of a State inventory of a specific class of designed landscapes.

[76] *Olmsted Historic Landscape Preservation Program: Guidelines and Criteria for Implementation* (Boston, MA: Commonwealth of Massachusetts Office of Environmental Affairs, April 1985).

[77] Timothy Keller and Genevieve P. Keller, "How To Evaluate and Nominate Designed Historic Landscapes," *National Register of Historic Places Bulletin 18*, U.S. Department of the Interior, National Park Service, in press.

Figure 2.—Categories of Historic Landscapes

	Treatment					
	Restoration	Rehabilitation	Reconstruction	Interpretation	Conservation	Typical landscape preservation projects
Residential grounds	K		#	#		Mary **Washington House, Fredericksburg, VA** **GWSM, Inc.** **The Garden Club of Virginia**
Monument grounds	H	Z		Y		**Statue of Liberty, New York, NY** **Norman T.** Newton National Park Service
Public building grounds	<	~				Original Governor's Mansion, Helena, MT Richard E. Mayer Montana State Parks Division
Garden	ti	~	~			Stratford Garden Restoration, Potomac River, VA GWSM, Inc. The Garden Club of Virginia
Minor public grounds (e.g., town square, parklet, traffic circle)	~			/		**Pioneer Square, Seattle,** WA Jones & Jones City of Seattle
Botanical garden	H	~			H	Sannonburg Gardens, Canandaigua, NY Noredo A. Rotunno Sannonburg Gardens Committee
Fort	~	~		H		Fort Stanwix National Monument, Rome, NY Dureya & Wilhelmi, P.C. National Park Service
Battlefield		/		/	/	Rosebud Battlefield, Montana **Richard E. Mayer** **Montana State Parks Division**
Cemetery		/			fl	**Cemeteries, New Harmony, IN** **Kane & Carruth, P.C.**
Streetscape		✓		1-		**Main Street Project, Hot Springs, SD** Preservation/Urban/Design, Inc. National Trust Chicago Mid-West Office
Estate	H	~			/	Gamble Plantation, Manatee County, FL **Lane L. Marshall & Associates, Inc.** **State of Florida**
Park		#		#	/	Cherokee Park Restoration, Louisville, KY **Johnson, Johnson & Roy, Inc.** **Louisville Metropolitan Park & Recreation Board**
Working farm	~		e			Old World Wisconsin, Eagle, WI **William H. Tishler** **State Historical** Society of Wisconsin
Museum village	✓	✓	✓			Williamsburg, VA Shurciiff, Hopkins, Parker, Barton & Belden — Staff Landscape Architects Colonial Williamsburg Foundation
District	<			#	#	Heritage Square, Los Angeles, CA **Merrill W. Winans** **Cultural Heritage Foundation**
Town		/		/	H	**Town of New Harmony, New Harmony,** IN Kane & Carruth, P.C.
Prehistoric site				/	/	Cahokia Mounds, near East St. Louis, IL Edward J. Keating Illinois Department of Conservation
Park system		/		#	/	Survey Olmsted Parks System, Buffalo, NY Patricia M. O'Donnell Highways, Parks & Recreation Historical Preservation Division & Landmark Society of the Niagara Frontier

SOURCE: *Landscape Architecture,* January 1981 sought State or National help in preserving it. However, in landscapes, the local constituency that identifies landscape value often do not exist, in part because adequate information is not available. For example, in the case of designed historic landscapes, most people are unaware that they were designed, and why it may be important to maintain the integrity of that design. For cultural or vernacular landscapes, the local constituency may appreciate their significance the least just because they are so familiar.

Where a constituency has developed, it has often acted to enlarge the scope of historic districts. For example, in Jefferson County, Kentucky,[78] a site consisting of a few farm houses and auxiliary buildings was nominated to the Register. However, the local people realized that the houses had little to do with the significance of the area. They considered the agricultural patterns, the associations of the families the stonework, the fences, and other components as significant. The local people, working through their certified local government (CLG), did the research necessary to expand the scale of the nomination to a 400-to 500-acre district. The landscape elements became major components imparting significance to the district.

As citizens become more aware of the influence of historic landscapes in their lives and landscapes' importance to the history of the Nation, local nominations to the National Register of Historic Places are likely to increase in number and size.

2. *Landscape records are often poorly stored and cataloged.*

One of the important components of surveying the States for additional significant historic landscapes is to be aware of those already cataloged. Unfortunately, the state of knowledge of sites so identified is quite poor; until quite recently, it was not possible to use even the National Register of Historic Places as a source to compile a list of significant landscapes because the Register does not list them as landscapes but as structures, if at all. In many cases, landscapes are included on the National Register by virtue of the fact that they are settings for historic structures. In some cases, the landscape may have greater significance than the structure.

The contents of the National Register are now in a computer database, which should make it possible to locate nearly all landscapes listed in the National Register. **Improving local and national databases and making historical data generally more available should improve the quality and extent of landscape preservation.**

3. *Landscape study is highly interdisciplinary.*

The study of prehistoric and historic landscapes requires the use of a variety of information sources, including folklore, oral history,[79] historic maps, drawings, and paintings, climate information, tax records, and ethnohistorical accounts. Analysis draws on a variety of techniques, including sociological techniques, environmental design, and a variety of geographical techniques developed for the analysis of land cover and landforms. This characteristic is one of the strengths of landscape preservation. Because landscapes often transcend political boundaries, they may be profitably studied on a regional, as well as multidisciplinary, basis. The study of landscapes and the study of ecology both share such a regional scope.[80]

4. *Landscapes are subject to a variety of stresses that change their condition and character over time.*

Because landscapes can change so radically over time as a result of urban development, the growth of bushes and trees, and wind and rain erosion (see *Chapter 4: Restoration, Conservation, Maintenance, and Protection* for discussion of such stresses), it may be extremely difficult to locate the full extent of cultural and historic designed landscapes in the midst of radically altered surroundings and successive changes. Landscapes may either increase or decrease in significance depending on their integrity and surroundings.

[78]Timothy Keller, Land and Community Associates, personal communication, 1986.

[79]See, for example, Mary Hufford, "Culture and Cultivation of Nature: The Pinelands National Reserve, " *Folklife Annual* 1985 (Washington, DC: Library of Congress, 1985).

[80]For example, several rivers that start in the Blue Ridge Mountains of Virginia empty into the Atlantic in North and South Carolina. The environmental problems caused by human use of these rivers are indeed regional.

One of the biggest technical problems in understanding cultural landscapes is that different cultural components of the same landscape are generally associated with several different periods of history. Both cultural and ecological factors can cause irreversible changes that further complicate study of the landscape. Disentangling these various components and understanding how different ages shaped the landscape to fit their purposes can be a formidable task. Unless researchers can untangle the various components of different periods it is nearly impossible to reconstruct a landscape perfectly for any one period.[81]

For example, one study[82] of the historic landscapes around Mont Dardon in southern Burgundy found that the pre-Christian era Celts responded to the land much differently than their Roman conquerors, who altered the landscape to suit their military needs, The Celts preferred to live on the more easily defendable heights, but the Remans forced them to move into the valleys where their army could control them more easily. Inhabitants from the Middle Ages and the modern periods in their turn dramatically altered the Roman landscape. Even in North America, where written records are only a few hundred years old, cultural manipulation of the landscape may involve many different cultures extending more than 10,000 years into the past.

5. *Appropriate application of existing technology is important.*

The locations of many designed gardens or parks are known because they are part of local lore. However, they may be buried, or so altered in appearance that they are unrecognizable. In these cases, landscape architects and historians employ well-known, standard archaeological and historical research techniques to determine their original extent, form, and contents. For example, the existence of the terraced garden associated with the Paca House, the winter home of William Paca, one of the signers of the Declaration of independence, in the city of Annapolis, was well known from 18th century historical accounts. However, when restoration of the Paca House began in 1965, the original garden was buried under a parking lot and only a few details of its extent, form, and contents were provided in these writings. No drawing of the garden existed. The current Paca garden is a conjectural reconstruction developed from detailed archaeology of the immediate area and considerable historical research on the types of flowers, shrubs, and trees that Paca would have likely planted .83

6. *The techniques appropriate to different size landscapes are different.*

Cultural Landscapes.–Computer modeling and remote sensing techniques provide a powerful set of tools for the interpretation and evaluation of cultural landscapes, which may extend over hundreds or thousands of acres. An important goal of the investigator of a prehistoric or historic landscape is to be able to "read" the landscape for the clues (or signatures) it gives to the relationships human societies bear to the land and how they interact with and alter it over time. Technology can aid that process by making the varieties of information about landscapes much more accessible. Such systems can be used to plot the potential changes to a landscape as a result of plant growth, grazing, forestry, and other temporal alterations of landscape components.

In discussing the use of such advanced techniques, participants in this study noted that many administrators who control the purse strings regard GIS, remote sensing, and other advanced methods as expensive, yet for large areas, it can be one of the cheapest methods for gathering data, especially because it allows access to information impossible to retrieve in any other way. public administrators need to understand how remote sensing may be cost-effective in certain applications. They also need to understand the limi-

[81] For example, 17th century Salem, MA, had structures and land use patterns which originated in, and were characteristic of, the 16th century.

[82] Carole L. Crum Icy, "Archaeological Reconnaissance at Mont Dardon, France," *Archaeology,* May-June 1983, pp. 14-17, 20; and Scott L.H. Madry, "Remote Sensing in Archaeology, " *Archaeology,* May-June 1983, pp. 18-19. They used remote sensing and computer analysis, as well as traditional historical and archaeological research methods, to investigate the patterns of two millenia of settlement and land use in the area. Their goal was to illuminate the ways in which different cultures have defined and used the local landscape.

[83] Bill McDougald, "William Paca's Colonial Garden, " *Southern Living,* May 1984.

Wiiiiam Paca House and Garden, Annapoiis, MD

Photo credit: Ray A. Williamson

After being buried under a 200-room hotel, a parking lot, and bus station, this 18th century garden was restored in the 1970s based on the results of careful research by archaeologists, architects, landscape architects, and historians.

tations of such technology in order to avoid applying it inappropriately.

Designed Landscapes.–For historic parks, gardens, and other designed landscapes, remote sensing and GIS find less application. Searches of historical records and traditional archaeological and botanical techniques are the techniques of choice. Many of these techniques may be improved through the innovative use of computer hardware and software. (See, for example, Chapter *5: Preservation In formation.)*

Historic landscape analysis and evaluation also require the identification, study, and retrieval of historic plant types. Identifying the plants appropriate to a given historic period and region is one of the major tasks facing landscape preservationists. Their task is complicated by the fact that plant taxonomies have changed radically over time. In addition, thousands of varieties of trees, shrubs, and plants have been introduced into the United States from other parts of the world over the past 200 years. Certain varieties, such as the American chestnut, have virtually died out. Finally, locating historic varieties is rendered more intricate by the fact that many varieties now sold are hybrids. There is a critical need to develop appropriate databases on the types of plantings used in historic times, and current sources of historic plant stock. There is also a strong need to encourage growing the stock itself.

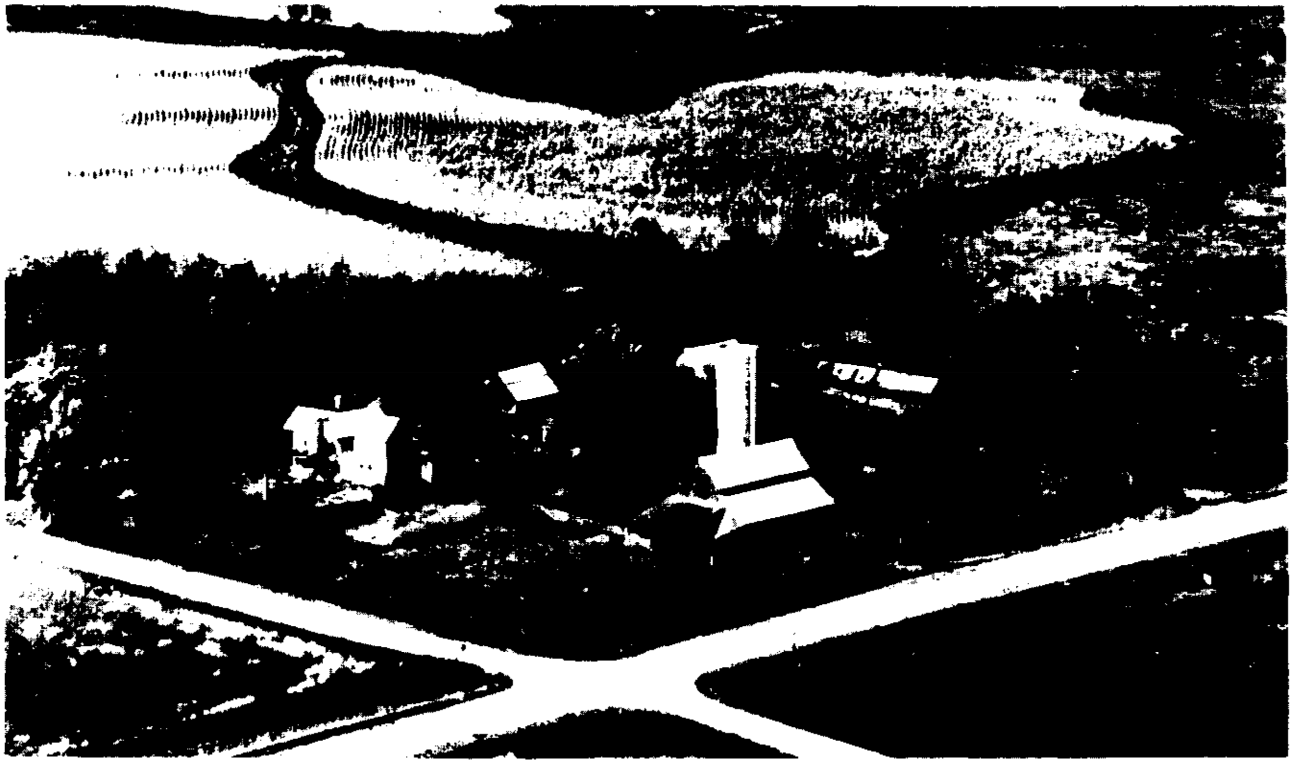

Photo credit: Jon D. Findley

Cultural landscape: the Findley Homestead, Dallas County, Iowa, early 1980s.

7. Qualitative techniques have an important ***role in the study of landscapes.***

In analyzing a landscape for such purposes as restoration or park redesign, it is important to be aware of the varied cultural values of the local citizens. Qualitative anthropological or historical techniques, such as interviewing, can be used to understand the values of the different constituencies to relate them to the needs of the entire community. For publicly owned landscapes, such techniques applied in conjunction with those of the landscape architect or designer may significantly enrich the quality of the preservation effort .[84]

[84] See Scott S. Weinberg, "Environmental Quality Points: A Land Management System, " *Landscape Architecture Magazine,* May/June 1985, pp. 97-98. For a more complete treatment, see Scott S. Weinberg, "Environmental Quality Points, " manuscript, School of Environ mental Design, University of Georgia, 1985.

8. Known technologies can be adapted for computer and other applications.

One of the major tasks facing landscape preservationists is to adapt known technologies to new settings. For example, the use of pin bar registration techniques to produce overlays is well known to architects and landscape architects. Such overlay drafting techniques allow landscape architects to produce different drawings for different landscape components (e.g., structures, walls, trees, and shrubs) and then overlay them on one another. Because they are line drawings, pin bar drawings can easily be digitized for manipulation in a minicomputer or microcomputer using computer-aided design software. They can be used to compare historical drawings with the current condition of the landscape. With the computer, and the appropriate software, it is possible to vary the scale, add and subtract components, and print out the results on a variety of printers.