CHAPTER 15

From Raritan Landing to Albany's Riverfront: The Path Toward Total 3D Archaeological Site Recording

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Introduction

Karen Hartgen of Hartgen Archeological Associates, Inc., called me Friday evening of the July 4th weekend in 1999. Her message was explicit and urgent. After 3 weeks of excavation along the former riverfront of Albany, New York, her archaeological team had exposed a complex, 300-foot-long matrix of deeply buried log bulkhead structures of the original colonial port settlement (Figure 15.1). The excavation had run out of time, and I was asked to develop a strategy to provide a high-speed recording solution over the weekend and to deploy a team by the following Wednesday. In response, I implemented the dual application of high-resolution single-camera photogrammetry in conjunction with the first use in archaeology of the recently developed three dimensional (3D) laser-radar scanning technology (LIDAR) to produce a 3D record of the site over two 3-day recording sessions in July and August. This chapter presents examples from case studies in archaeological rescue excavations over two decades (1978–1999) to review the precedents and decision-making processes that led me to recommend the dual use of these systems to record a complex archaeological site in record time.

Innovation for Conflict Resolution

These applied technology solutions are deployed to aid in the rapid, accurate, and safe investigation of generally two contexts: emergency rescue excavations of unexpected archaeological discoveries and archaeological discoveries beyond the reach of traditional field approaches, due to contamination or other impediments (Grossman 1978, 1980, 1982a, 1985, 1990a, 1990b, 1995, 1997).

Over the past 20 years, and particularly after a series of high-altitude expeditions in the pre-Inca highlands of Andean Peru, my work has often involved archaeological crisis management, directing projects interrupted because of unexpected archaeological discoveries. These unexpected discoveries have included unknown Native American and colonial burial grounds, which could have precipitated serious ethnic and/or political conflicts, buried historical settlements thought to have been long gone, and on occasion, military secrets that got lost or buried in the physical and archival record.

Regardless of the causes, these situations can be traumatic, expensive, and politically volatile. They require quick and often innovative approaches by all involved. Agencies and corporations have to evaluate and authorize new scopes of work, project schedules, and budgets. Archaeologists need to provide quick and precise answers to difficult questions. How big is the buried site? How deep is it? What are its limits? Is it important? Does it have sufficient stratigraphic integrity to warrant National Register eligibility? How can the project be redesigned to minimize or avoid impacts? If in need of in-depth documentation, can it be cost effectively recorded without causing undue delays in the interrupted construction program?

My use of applied technology to help answer some of these questions has been based on two consistent assumptions. First, that the resolution of environ-

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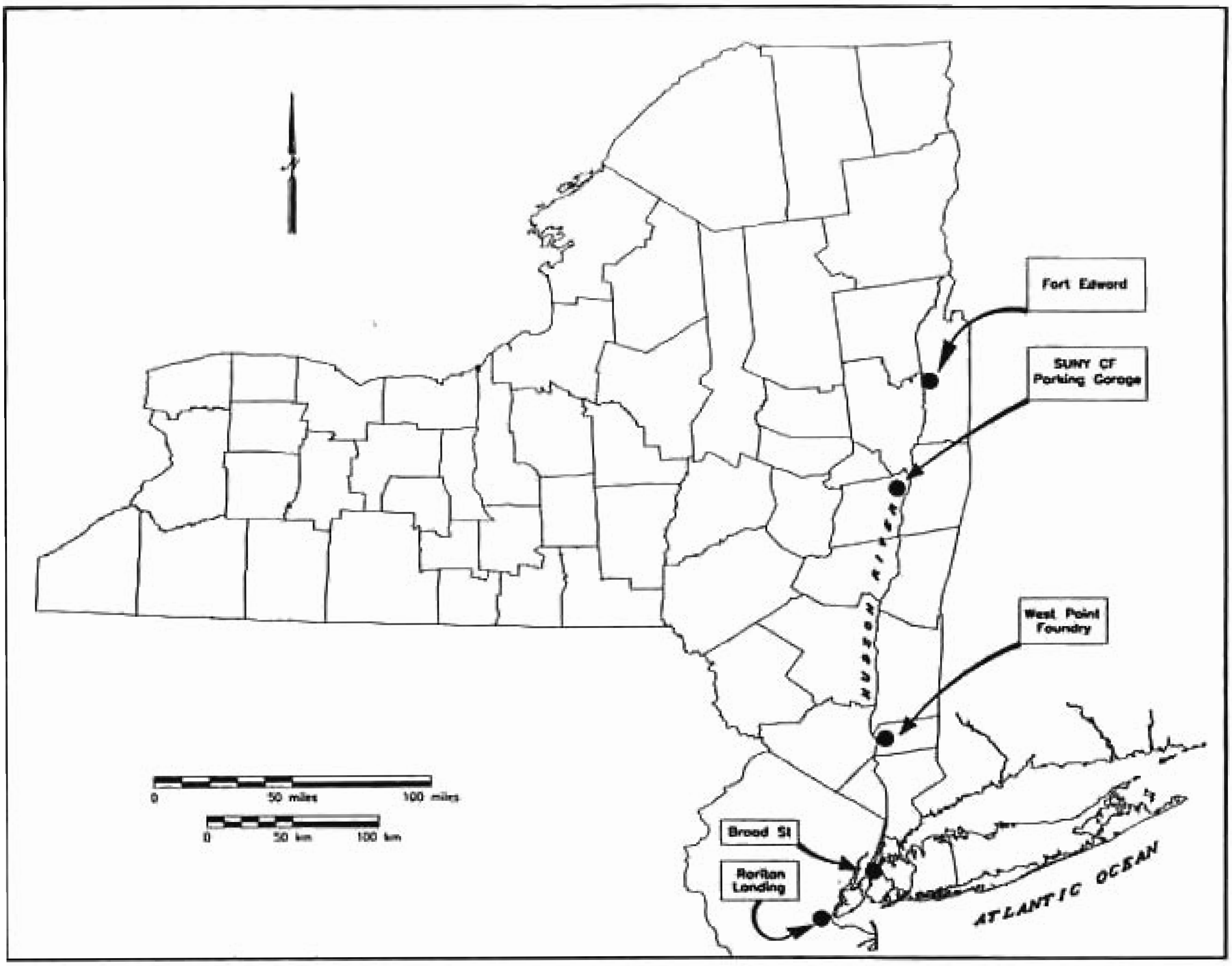

Figure 15.1. Locations of sites discussed in this chapter.

mental conflicts and the ability to quickly develop viable mitigation strategies depends on high levels of definition and data control. Second, that the long-term value of our work depends on the quality, clarity, thoroughness, and precision of our data recording, not on our individual theoretical or interpretative orientations.

Within this high-pressure environment, it was also often necessary to alter the traditional approaches and time frames of archaeology with innovative strategies to increase efficiency or reduce exposure to harmful environments. All of the projects discussed here took place in restricted time frames, and three occurred in adverse deep-winter conditions under heated shelters. All required fresh approaches to meet the challenges of site definition and documentation in often contaminated settings, which over the past 10 years have included the need to excavate through archaeological deposits laced with cadmium, arsenic, lead, toxic organics, radiation, and unexploded ordnance (Grossman 1990a, 1993, 1994a, 1994b). Instead of random sampling, ground-penetrating radar and other geophysical devices were applied to provide target-specific testing strategies. Instead of traditional fair-weather time schedules, heated steel-reinforced domes with massive heaters and dewatering systems were built to thaw the ground, protect the scientist and artifacts, and permit 24-hour-a-day excavation, even in most severe winter conditions. Instead of laborious measuring tapes, line levels, and rulers, 3D lasers and 3D cameras were employed to provide precise survey and point provenience records in minutes and seconds.

And if the archaeological study was conducted at a contaminated site, usually as part of federally mandated investigations of superfund sites, the large multidisciplinary field and laboratory teams required special training, medical monitoring, protective plastic suits, and daily decontamination after excavation. The handling of contaminated cultural remains in turn mandated the need for building safe onsite decontamination and artifact processing, computer inventory, conservation and documentation laboratories to facilitate concurrent data control and rapid decision making. This discussion is restricted in scope to the applied technology dedicated to enhance the speed and level of definition in site recording.

Precedents and Borrowed Solutions

All of the technologies discussed, single and stereo cameras, metric cameras, electronic transits, geophysical techniques, and, most recently laser-radar scans, were selected and adopted from other disciplines and scientific contexts. Each had met the test of usefulness, field readiness, and potential benefits following 2 to 5 years of demonstrated effectiveness in other fields. Their usefulness as more efficient, precise, or cost-effective than previous archaeological solutions had to be proven. When faced with the real pressures of time and expense, one must choose tried, easily available, and cost-effective solutions or technical aids, rather than the newest or the most advanced, yet untested, technology, which may or may not be reliable.

Overhead bipod systems had been actively under development and deployed by archaeologists since the early 1960s (Whittlesey 1975:258). Computer transit survey and measuring systems had been demonstrated to be faster than optical systems for a Near Eastern mapping expedition a year before they were applied at Raritan Landing in 1978 (Sterud, Strauss, and Abramovitz 1980). Likewise, 2 years before it was first used for archaeological recording in Albany, laser-radar technology had been whole-heartedly applied to replace the more time consuming and less accurate photogrammetry by major oil companies to map existing conditions and complex piping systems on offshore platforms, and by the movie industry. Almost at the same time, Jack W. LeRoy and Associates independently applied the Cyrax laser scanner in May of 1999, 2 months before its use in Albany, to make a 3D map of the National Park Service Oregon Caves National Monument (St. Amand 1999).

Benchmark Case Studies of Applied Technology: 1978–1999

The following case studies focus not on the technical details of how each class of applied technology works, but instead on how and why they were deployed. In each instance, these examples of applied technology were deployed to augment or supersede the limitations of traditional manual and optical field-recording procedures and to do justice to threatened archaeological resources in a timely, feasible, and cost-effective manner.

Five large-scale data recovery excavations spanning two decades will serve to define three phases of development or benchmarks in the quest for faster and more intensive recording systems (Figure 15.1). The first phase or period was marked by the initial use in 1978 of low elevation overhead stereo pair photogrammetry in conjunction with high-speed computer transit equipment to record the pre-Revolutionary War port community of Raritan Landing, a buried colonial site complex belatedly discovered during construction (Grossman 1978, 1980, 1982b). Given its initial success, the same approach was subsequently applied to provide the core recording system for the 1984 winter excavation of the deeply buried Dutch West India Company site found preserved beneath the financial district of lower Manhattan (Grossman 1985). The full power of these new systems with the advent of integrated data collectors with automatic coordinate conversion was fully implemented and tested in 1986 at Fort Edward, New York (Grossman 1990b).

The second phase, which began in 1989 with the excavation of Civil War gun testing facilities at West Point Foundry, was marked by the first archaeological use of single-camera photogrammetric recording and software interpolation systems to overcome the limitations of fixed dual camera setups and to facilitate the first federally mandated archaeological mitigation of a superfund site (Grossman 1990a, 1994a, 1997; Holtzer 1995).

The third phase began in the summer of 1999 with the first archaeological use of 3D laser radar in tandem with computer transit and low elevation photogrammetric systems to help document the 300-foot-long discovery of buried colonial shoreline remains in Albany, New York.

Early Computer Transit and Overhead Stereo Photogrammetry Systems

My initial experience using computer transit systems for rapid grid and 3D data control and low elevation site-specific photogrammetry took place in 1978 with the unexpected discovery of the 1730 colonial remains of Raritan Landing found buried under 3 feet of rock fill in the flood plain of the Raritan River opposite modern New Brunswick, New Jersey (Figure 15.2). The need for high-speed and high-precision recording approaches was driven by the presence of archaeological remains in the construction corridor of a federal sewer line. Scaled historical maps and ground penetrating radar were used to define the location and extent of buried structural remains (Grossman 1978, 1980). A 20-foot-wide by 300-foot-long corridor was fully excavated with wide area exposure techniques to reveal several pre-Revolutionary War structures and two well-preserved, buried, colonial period, ground surfaces with diverse artifact concentrations, building foundations, historical pit features, and preserved foot prints in the buried mud.

The federally funded construction was stopped, financial and political pressures were building to address the unexpected discovery in the shortest time possible, and the responsible agencies were under comparable pressure to do justice to the important discovery by documenting any impacts to the highest scientific and legal standards. Because of its size and stratigraphic complexity, the wide-area exposure and documentation of the complex multicomponent historic structural remains could not have been done quickly using traditional manual recording techniques. With few options, I proposed to expedite the excavation process with the intensive application of two new recording procedures. One consisted of the use of recently developed high-precision electronic survey equipment for high-speed coordinate and provenience control; the other was an adaptation of a British-developed, bipod suspended overhead photo mosaic and stereoscopic recording system to rapidly capture a detailed record of the site.

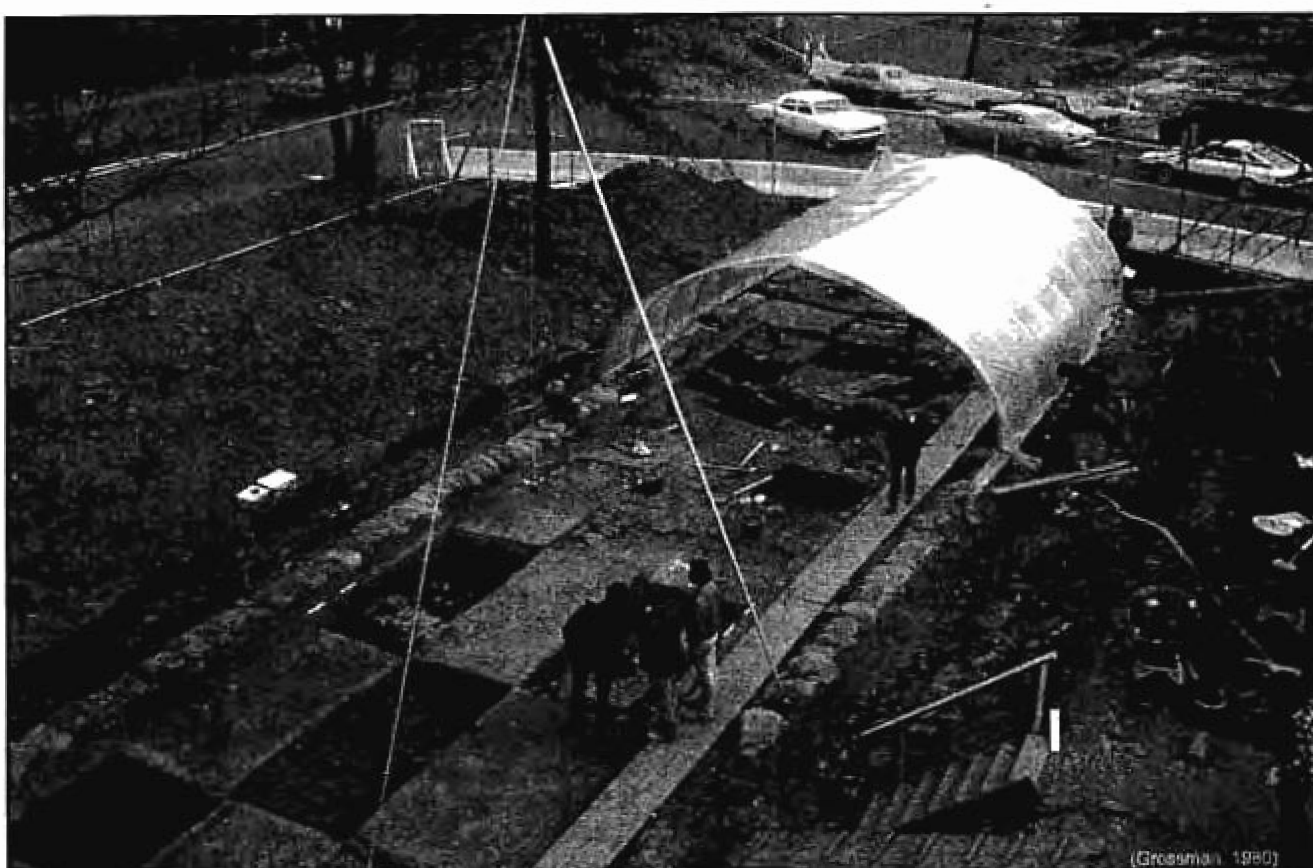

Figure 15.2. View of Raritan Landing 1979 excavation of the EPA impact corridor showing the derivation of Whittlesey bipod camera support system.

High Precision Computer Transit Systems

Beginning in the mid-1970s, the computerized electronic distance meter first became available to commercial survey and engineering professionals as a cost-saving solution to the tedium and imprecision of traditional optical transit and manual surveying techniques. The new electronic transit systems were capable of measuring the location of survey points, or objects, as angles and distances with a precision of several centimeters in a kilometer (and in millimeters at distances of hundreds of meters). The first models had little or no computing power, were referred to as electronic distance meters (EDM), and were limited in output to measurements of angle and distance. The electronic transit measures the distance in the time it takes the near laser infrared beam to bounce back to the instrument off of a prismatic mirror reflector attached to a stadia rod over a target, provenience point, or artifact. When combined with measurements of the transit's vertical and horizontal angles relative to the target, true coordinates can be computed using standard trigonometric formulas. Each reading takes approximately 4 seconds.

The availability and potential utility of this new technology for high-speed field recording in archaeology was brought to my attention by Dr. Gene Sterud who used an early EDM or electronic transit to map the large site of Sardis, Turkey, in 1977 (Sterud, Strauss, and Abramovitz 1980). He informed me of their successful application at other large urban sites in the Near East and Mayan Lowlands (Miller 1978; Weeks 1978). Based on this precedent, and my need to deploy a high-speed data recovery plan workable under shelter in winter conditions in a matter of weeks instead of months, I recommended the same EDM system for the emergency rescue excavation at Raritan Landing in 1978 (Grossman 1978, 1980, 1982b).

The first challenge to its use as an efficient high-speed field tool came out of the need to automate the data collection and coordinate conversion tasks. Until the mid-1980s, actual coordinates from optical transit systems had to be computed individually with a hand calculator and trigonometric formulas or by linking the EDM to an early portable computer. A mixture of both commercial and in-house software routines was programmed in Basic to link, process, and store the transit readings. At Raritan Landing in 1978, and subsequently for the 1984 excavation of the seventeenth-century Dutch West India site in Lower Manhattan, this hardware interface was accomplished with early portable computers, first with a 32k Epson CPM machine with a microcassette data storage unit, and then in 1984 by a ROM-based Radio Shack Model 100 portable (Grossman 1982b, 1985). The task of programming these early onsite data collectors was aided by previous efforts by archaeologists throughout the 1970s to use early scientific calculators for the conversion of optical transit readings to site coordinates in the field (Blakeslee 1979; Hakiel 1980; Rick 1980; Wittlesey 1980). Although functional, these early in-house stop-gap solutions suffered from unreliability, vulnerability to the elements, and to software bugs that made them quirky to operate.

By the mid-1980s, several manufacturers had introduced EDM instruments with built-in or integrated data collectors and computers capable of instantly converting and recording each angle and distance reading into a site-specific set of x, y, z coordinates with typed-in provenience or descriptive data for each record. In the summer of 1986, I deployed one of these early integrated total station systems to record the unexpected discovery of a large multicomponent historic and precontact site complex along the banks of the upper Hudson River in Fort Edward, New York. The deeply stratified site revealed first the bastion of eighteenth century Fort Edward above an extensive 400,000-square-foot Late Woodland site containing more than 900 Native American pit features, burials, and structural remains. A 3000-year-old Transitional Period Broad Spear occupation consisting of cobble platform cooking hearths, undisturbed living floors, and 80,000 chipped stone artifacts was found 5 feet below the Late Woodland Period site (Grossman 1990b).

As was the case with the unexpected discovery at Raritan Landing 8 years earlier, the magnitude and timing of the discovery at Fort Edward threatened the viability of a federally funded public works program, in this instance, a much needed water treatment facility. The challenge was made more acute by the sheer size and complexity of the site. It also underscored the urgent need to define and record the point locations of literally thousands of features and artifacts in a restricted time frame of weeks versus months or years.

The advent of this one category of adapted commercial digital surveying equipment has affected archaeological field strategy in three primary areas: (1) It provides enhanced speed and precision to meet the time constraints of emergency field situations; (2) it increases the archaeologist's ability to provide micro topographic and artifact density and distribution records essential for the identification of behaviorally significant activity and settlement patterns; and (3) it provides the essential data control and precise reference targets for both single camera photogrammetry and LIDAR coordinate scans.

Overhead Stereo Photogrammetry

The idea of low elevation overhead photography in archaeology was not new. Aerial photographic coverage came into use with balloon reconnaissance during the Civil War and World War I. From this foundation, archaeologists experimented using ladders, balloons, model airplanes and helicopters, multilevel mono and bipod suspension systems with varying success (Bevan 1975a, 1975b; Sterud and Pratt 1975). Overhead recording technology involved two major components: first, the recording system itself, and, second and of equal developmental challenge, a system to suspend and support the recording technology over the excavation to provide overhead and 360-degree coverage from a number of different angles, such as near eye level, at 45 degrees, and at nearly overhead vertical coverage.

By the early 1970s, Julian Wittlesey had designed and subsequently patented a ready-to-use lightweight bipod system for archaeologists (Wittlesey 1975). Although the time frame of the Raritan Landing project made it impossible to acquire any available examples, Wittlesey kindly provided his blueprints to build one for the Raritan Landing dig. The only limitation of the existing design had to do with controlling the orientation of the camera, which, when raised, would often spin. Given the 20-foot by 300-foot area of the Raritan Landing excavation corridor, it was necessary to develop a camera locking system to orient the photographs in line with the grid and thus reduce the number of setups and exposures required to guarantee full coverage with the least number of shots.

My team at the Rutgers Archaeological Survey Office (RASO) designed and built a version of the Whittlesey bipod system with a custom-built beaklike overhead camera mounting mechanism to lock the camera into alignment with the site grid not unlike the docking bay on the International Space Station. When raised by pulley and suspension cables to the apex of the triangular bipod legs, the camera (a Hasselblad with an 80-mm macro lens) was able to capture a flat field image of a 15-foot by 15-foot square of nine adjacent 5-foot excavation units in each view. Several different systems were adopted to trigger the camera remotely while suspended (wire-cable-, air-cable-, and remote-radio-controlled firing devices). By tilting the bipods with cables over a ca. 20-degree arc, the overhead camera system was able to capture stereo coverage with 30 to 60 percent overlap. The resultant coverage provided details of the buried living surfaces, not otherwise visible (Figure 15.3) (Grossman 1978, 1980, 1982b).

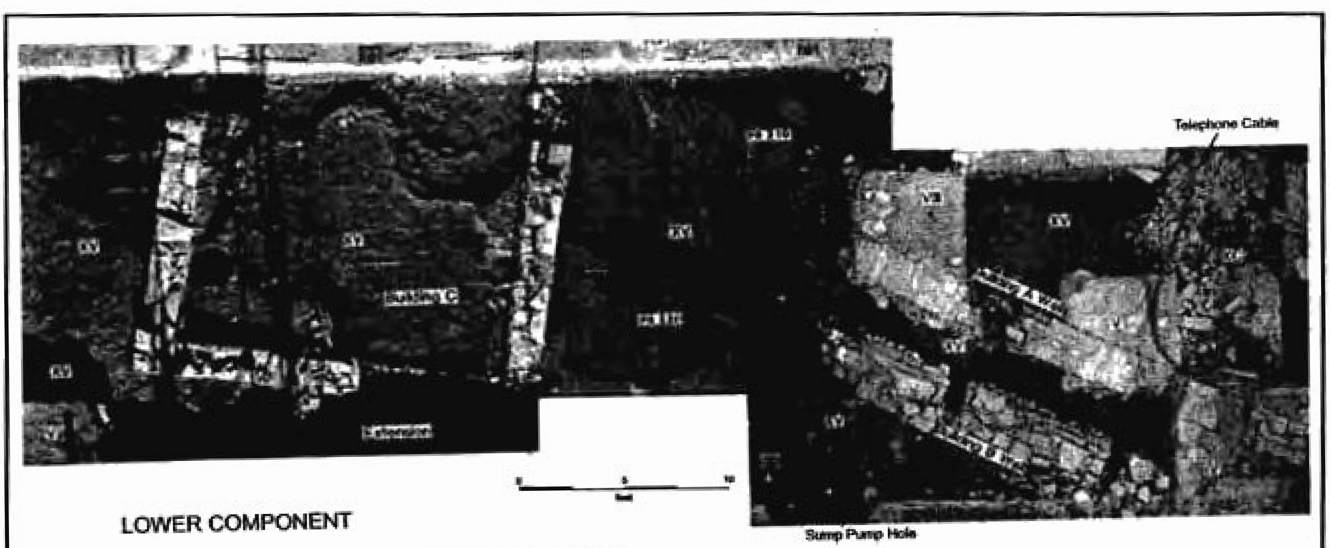

Figure 15.3. Photomosaic of overlapping bipod image segments into single rectified overhead composite image of the earliest eighteenth-century building elements within Raritan Landing construction corridor.

This system needs both height and fair weather. Although much of the excavation occurred during the winter, the bipod worked at Raritan Landing because the air-inflated, steel-ribbed, and plastic-covered, customized "green house" shelters over the site could be moved and slid apart to permit the raising of the camera-mounting system. Although excellent for fair weather, because of its height and the impossibility of moving the fixed 8-foot-high heated winter shelters, this suspension system was not a viable solution 5 years later for the high-speed winter excavation of the mid-seventeenth-century remains of the Dutch West India Company site (Grossman 1985).

Low Elevation Overhead Photogrammetry Under Winter Shelters

In 1983 the large-scale rescue excavation of the former shoreline block of Pearl Street between Broad Street and Whitehall Street in Lower Manhattan led to the discovery of the well-preserved early seventeenth-century remains of the Dutch West India Company, as well as the pre-1650 homes and artifacts of some of its principal residents. The excavation conducted by Greenhouse Consultants Inc., for which I then served as principal investigator, revealed the presence of five periods of early Dutch and British stratified historic deposits (Grossman 1985).

Beneath the basement fill and brick floors of nineteenth-century buildings, the archaeologists exposed the relatively undisturbed, seventeenth-century fastland surface, the well-preserved stone foundation remains of a number of buildings, some with early seventeenth-century cobblestone interior floors and features of imported yellow brick from Holland. These structural remains included the pre-1651 warehouse of Augustine Heermans, a principal trader of the Dutch West India Company, the wooden barrel cistern of Dr. and Mrs. Hans Kierstede, the company's first official surgeon, and the domestic remains of Cornelius van Tienhoven, the secretary of the province under Peter Stuyvesant after 1652 (Grossman 1985, 2000).

The Manhattan dig took place in deep winter conditions under fixed air-inflated and heated shelters with a maximum interior elevation of 8 feet to 10 feet. Because of the low elevation of the shelters and the severe weather conditions that prevented them from being even temporarily moved, the 20-foot-high elevated bipod system would not work. An alternative overhead photo recording system had to be developed. To solve this problem, I worked with a photographer and a metal engineer to design, machine lathe, and build a low-elevation indoor stereo camera suspension system that could be easily assembled and maneuvered beneath the winter shelters. After trying many variations on the theme, we designed and built a triangular single-track monorail camera support system suspended between two heavy photo tripods at a height of 7 feet to 8 feet, the allowable clearance at the sides of the shelters. A 3-foot-diameter rotating metal disc was milled from aluminum plate to mount the two cameras, one for black and white and one for color or infrared film. When spun and moved parallel to the excavation surface along the triangular suspension track, the circular mounting disk provided overlapping 30 to 60 percent stereo and photomosaic coverage at low interior elevations (Figure 15.4).

Figure 15.4. Detail of the 1983 custom-built, overhead-camera suspension system designed to provide low-elevation stereo and photomosaic coverage under winter shelters.

Although elegant and complicated in design and construction, and different in appearance than the 20-foot-tall Whittlesey bipod, it worked on the same principle and had similar drawbacks as the earlier bipod device. It was difficult to lock into place with precise coordinate control, was time consuming to assemble, stopped excavation in the immediate vicinity, and also had a bad habit of falling on people.

Single Camera Photogrammetry at West Point Foundry

Confronting Contamination

The next stage of increasingly more efficient and flexible stereo and photo mosaic recording capabilities began in 1989 with the first large-scale archaeological data recovery effort at a U.S. Environmental Protection Agency superfund remediation site at the Marathon Battery at West Point Foundry (Figure 15.5). This 5-year multiagency program of terrestrial and underwater archaeology resulted in the discovery of sensitive Civil War era cannon research and testing facilities under 5 feet of modern fill and cadmium deposits at the former site of the West Point Foundry across the Hudson River from the West Point Military Academy. The additional discovery of the elaborate houses and high-quality imported European artifacts and scientific instruments that belonged to well-educated foreign workers, as well as previously unrecorded archival evidence combined to reveal a previously unknown international intelligence and espionage operation within Lincoln's Executive Branch (Grossman 1990a, 1994a, 1994b; Holtzer 1995).

Like the Manhattan dig, the excavation had to be done in winter conditions under heavy shelters with limited access and mobility. Unlike the previous projects constrained only by time, as a superfund site,

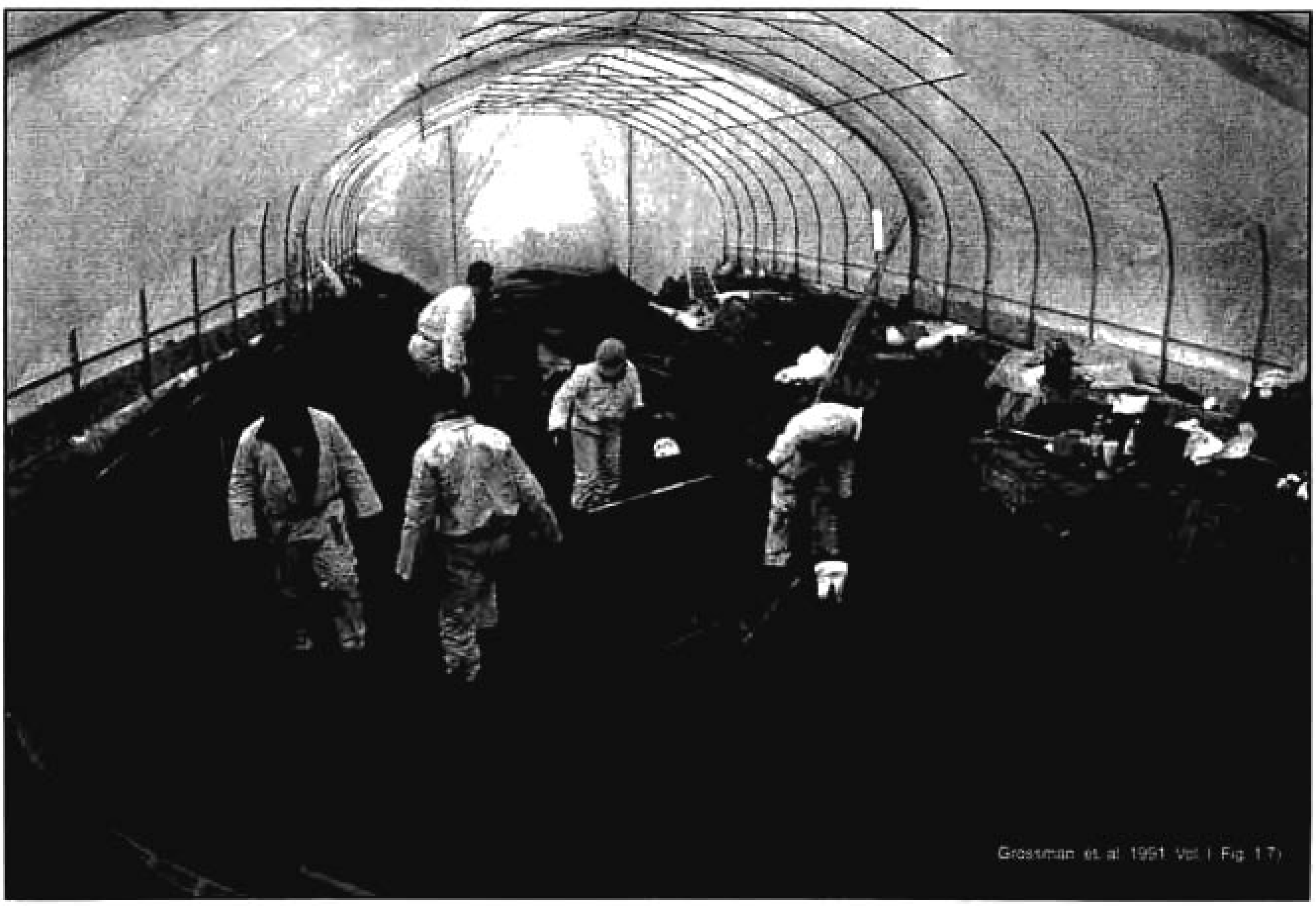

Figure 15.5. Grossman and Associates 1992 HAZMAT archaeological team excavating under fixed and heated winter shelters at the West Point Foundry.

Marathon Battery was contaminated with heavy deposits of cancer causing cadmium. Something safer than the earlier overhead systems was needed. The added element of having to work in contaminated contexts affected the planning and deployment of archaeological approaches and procedures in two critical ways. First, their presence required the field and laboratory team members to be trained and certified in HAZMAT health and safety procedures, wear somewhat awkward tyvek suits and thick layers of protective plastic gloves, and be medically monitored throughout the fieldwork. Second, the potential health risks mandated the need to limit the proximity and duration of contact with potentially contaminated cultural materials.

In addition to deploying the total station transit system, the solution was provided by a new generation of nonstereo, single-camera, photogrammetric recording systems. Called the Rolleimetric, the new-medium-format metric camera was developed in the mid-1980s by the Rollei Corporation of Germany to record rapidly and remotely crash and disaster scenes for military and police agencies. This system was applied archaeologically for the first time at the Marathon Battery (Grossman, 1990a, 1994a). In 1992 it was also applied to minimize the level of exposure and time for the archaeological recording of a Civil War-era gasholder house remains permeated with toxic organic liquids and fumes found buried beneath the modern Niagara Mohawk Power Corporation facility in Saratoga Springs, New York (Grossman 1993).

The Rolleimetric Single-Camera Photogrammetry System: A Non-Contact Recording Solution

The system is unique because it supersedes the rigid structure and limited recording capabilities of traditional two-camera, stereo photogrammetry configurations. Instead of using fixed, overhead stereo image pairs, the Rolleimetric system uses a single metric camera, and a high resolution, flat field, wide angle, automatic focus macro (90^{o}) lens, which provides a broad range of latitude in the elevation and angle of recording. The metric camera and lens system is associated with a sophisticated computer software package that digitizes, rectifies, and correlates different images or views of the same subject and renders the composite image as a high-resolution, metrically accurate, 2D and 3D plan, profile, or 3D wire frame image. Unlike traditional photogrammetric systems, this new capability does not require stringently regulated 30 to 60 percent overlapping coverage between adjacent photos, but instead provides coverage with a variable range of perspective views taken from four to six points.

The single camera system reduces field time, enhances the quality of the documentation process, and provides a level of data control that is difficult, if not impossible, to record using traditional procedures. For emergency rescue and contaminated contexts, the single camera Rollei system permits the operator to rapidly document the subject in minutes with minimal contact between the operator and the contaminated remains (Figure 15.6). In addition to making the recording process more accurate, faster, and safer, the resultant photogrammetric prints constitute both a high-resolution visual record, and what essentially amounts to a long-term photographic archive of each subject's coordinates, dimensions, and structural characteristics. This long-term record can be reinterpreted through the computer at any subsequent time to extract additional relevant coordinate information or to render new perspectives, as needed (Figures 15.7 and 15.8).

But the Rollei single-camera photogrammetric system also had some limitations. The early analysis software was expensive, difficult, and time consuming to use. When originally released by the Rollei Corporation in the late 1980s, the relative ease of use and cost of data processing were exacerbated by the fact that each of the images had to be rendered as high-quality, large-format color plates and then processed through manual digital procedures with two different sets of cumbersome and technically complicated software packages that were available only in German.

These limitations have now been superceded by new, high-capacity, desktop computer-based photogrammetric software interpretation programs costing only hundreds of dollars, but considerable time, staffing, and budgets are still needed to computer-process the large sets of photogrammetric data. In addition, although the single-camera Rollei system is effective for rendering computer-assisted design (CAD) drawings of rectangular structural elements, such as cut beams, wooden planks, or masonry walls, it is of limited use for the capture and rendition of a large number of irregular organic forms, such as the large wooden logs and branches exposed on the colonial Albany waterfront site.

I develop, mobilize, and implement a high-speed 3D recording solution by the Wednesday following the holiday weekend that would record the entire site complex. The New York State officials had asked that I develop and deploy an applied technology recording solution as I had used first in 1989 at the Marathon Battery. I was also asked not to immediately say no, but instead to think it over, hopefully with a solution over the weekend. The conditions were clearly stated. There was no lead or mobilization time.

The Solution

At first I was not optimistic. Nothing I had done in the past 20 years would be sufficient to meet the complexity and time frame of the Albany challenge. So, as

Figure 15.7. (left) Near-overhead Rolleimetric perspective image of an exposed iron and wood cannon-testing platform discovered at West Point Foundry.

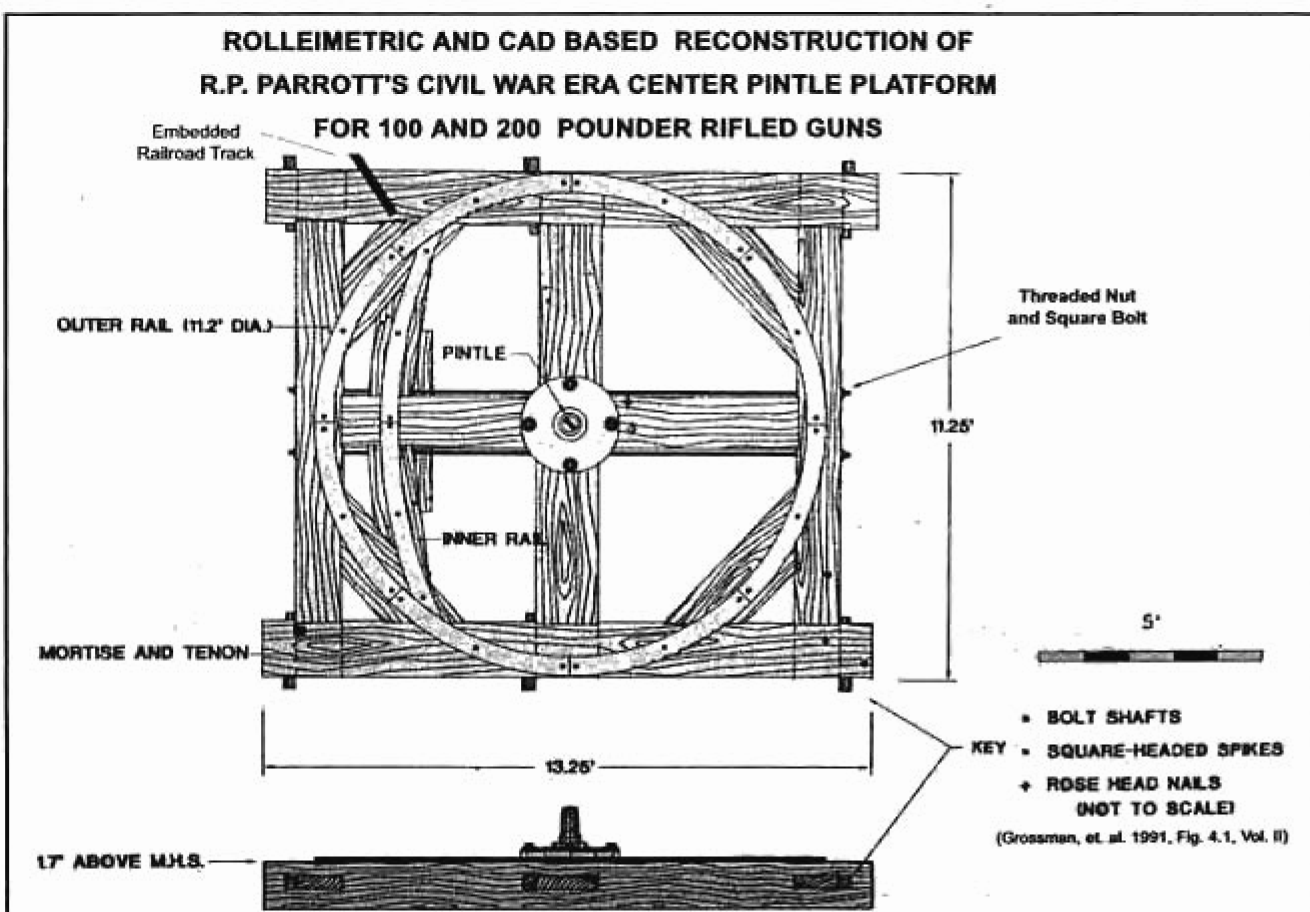

Figure 15.8. Final-scaled AutoCAD plan and profile record of excavated Civil War cannon-firing platform drawn from Rolleimetric photos.

Figure 15.9. Rolleimetric view looking southeast toward the Hudson River showing two-block-long excavation in Albany, New York.

I had done in previous challenging situations, I borrowed a new, but proven, high-speed recording technology from unrelated disciplines, the oil and movie industries. In addition to the previously used Rollei system to record hundreds of high-resolution, medium-format overhead and photogrammetric color images of the site, I recommended the first archaeological use of the Cyrax large-format 3D laser scanner (the Cyrax 2400 Mark-1) to capture an almost infinite series of millimeter-precise laser point clouds of x, y, z coordinate points for each log and beam of the Albany wharf and bulkhead complex.

Although untried in an archaeological setting, this recently developed 3D capture technology had been applied with enhanced precision over the best of photogrammetry to map complex structural details on oil platforms at sea, to develop realistic special effects and sets for the science fiction film *Star Ship Troopers* (where it helped giant flying bugs land on virtual reality interplanetary battlefields), and to guide robotic welding systems. It had also been used for a range of unspecified military and police applications (Ashley 1999; Cullison 1998; Cyra Technologies 1998). If it was good enough to help map intergalactic flying bugs, I made the determination that it was good enough to help record the large and complex historic archaeological matrix of the Albany excavation.

Photogrammetry has some severe limitations that affected my decision to augment its capabilities with the laser scanner technology. The relative merits of

Figure 15.10. View toward the southern section of excavation. LIDAR scanning in progress.

this new capability over the time and manpower constraints of traditional and even single-camera photogrammetry systems had been clearly defined in a scientific paper by Ashley (1999). It takes a trained specialist time and numerous steps to extract coordinate measurements. For complex structures, adequate coverage requires that a large number of metric views be taken, manually correlated, referenced to one another, and evaluated to extract detailed representations of the subject. The process is labor intensive and expensive, in terms of both film and processing costs and human hourly costs. Finally, while photogrammetry works fine for rectangular structural elements, such as a building, or the relatively limited number of square cut beams exposed in association with the Civil War cannon testing facilities at West Point, the Rolleimetric camera alone would become excessively time consuming and costly for a site consisting of thousands of irregularly rough cut logs uncovered in Albany.

I had been tracking the developmental progress of this and comparable large format 3D recording systems in the United States, Canada, and Europe for the past several years. A number of small laser scanner systems for small objects within a 1-foot to 5-foot range had been available from a variety of sources for some 5 years, but the first large-scale systems to be made commercially available on the open market dated only to 1998. The Cyrax system was still undergoing rapid developmental refinements, only 18 units were available worldwide, and it was still housed in a wooden box of dubious all-weather durability. If operational, available, and capable of doing for archaeology what it had provided the oil and movie industries, this new technology promised radically to alter how archaeologists could and would record their excavations with a potential for vast increases in detail and resolution, in a fraction of the time.

Over the weekend, I placed a call to the Cyra Corporation in California, the makers of the LIDAR laser scanner technology, and quite simply left a message with their answering service asking them to drop everything they were doing and fly their best people and equipment to Albany, New York, by the following Wednesday. On Sunday, a senior executive from Cyra called me back at home and, after a moment of guarded skepticism, agreed to do just that. Assuming the availability of immediate funding, he said yes, and so did I. The Cyra Technologies Corporation representative saw this as an ideal opportunity to test the rapid-response capability of their new systems. By Wednesday, the directors of the project, representatives of the New York State Historic Preservation Office, and senior administrators of the State University Construction Fund authorized and funded the deployment of the laser-radar team.

Looking like a large box-shaped transit on a tripod, this new large-scale, and highly portable, laser scanner is capable of capturing details of a three-dimensional structure with an accuracy of millimeters over a distance of 600 feet (Figure 15.11). In essence, the high-resolution 3D laser scanner developed by Cyrax can produce an extremely dense series of scans or point clouds, which in turn can be computer-rendered to create a mesh model of the subject. Officially known as LIDAR, the laser-radar technology can scan more points than either integrated total stations or photogrammetric reduction in a fraction of the time and cost. Each scan of a 50-foot portion of a site or grid matrix can typically contain 300,000- to 500,000-millimeter precise x, y, z coordinate points. When seamed together using software to georeference the various scans relative to the precisely measured coordinate control targets measured with the onsite computer transit, the multiple scans can be rendered into a CAD-compatible 3D mesh model from which accurate dimensions and locations can be extracted. Laser-based radar is not harmful to humans, and can work in full daylight or in total darkness.

The time frame for this rapidly mobilized, high-technology recording solution is only half the story. The 150-foot by 300-foot site was recorded in tandem with both systems. One major variable affecting the time frame hinged on how the two recording technologies would be raised and positioned to provide full coverage from all necessary angles. Given the lack of mobilization time to deploy both, a dedicated suspension system was out of the question. Instead of developing and building a system to provide wide area coverage of the two-block-long excavation, a 100-foot-high movable electronic lift or cherry picker provided unlimited 360-degree perspective views and near overhead coverage from the air for both the laser scans and hundreds of photogrammetric images (Figure 15.12).

The site was divided into eight 50-foot-square quadrants, four along the eastern side and four along the western side of the wide area exposure. Each quadrant was recorded from ground height, and then from the lift at 45 degrees, then 60 degrees, and finally with vertical and near overhead views from

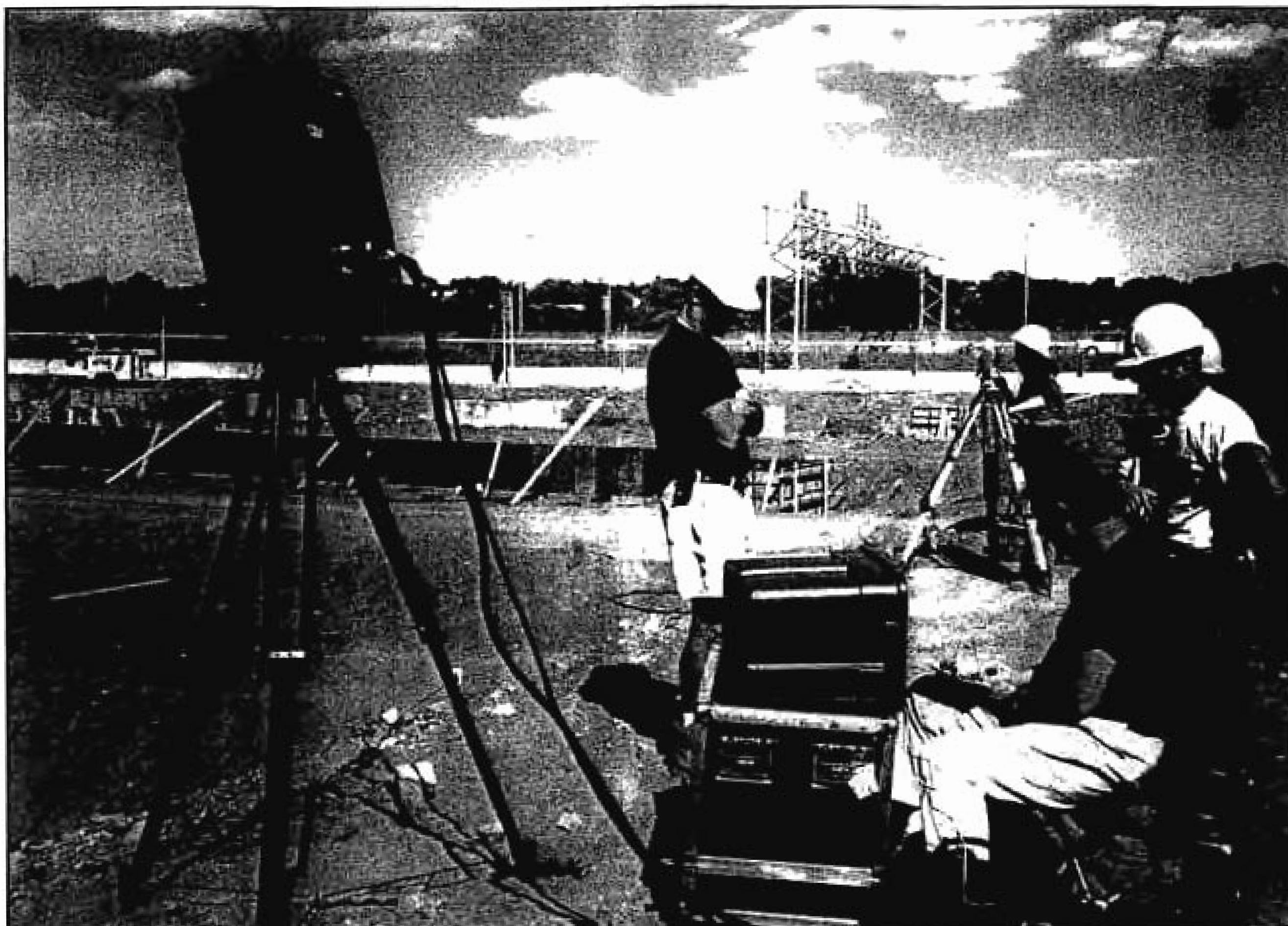

Figure 15.11. Three-dimensional Cyra LIDAR scanner equipment and technical support team mapping exposed bulkhead features.

eight side and corner positions within each quadrant. For each 50-foot by 50-foot recording quadrant, a total of between 24 and 30 Rolliemetric images were recorded to provide flat-field planar overhead and overlapping perspective views adequate for photogrammetric reduction and 3D reconstruction of each structural element exposed at the site.

The two teams, the Cyra staff manning the laser and I taking the overhead metric images, worked in tandem. When one was recording from the ground, the other was taking shots from the lift and vice versa. The eastern half of the site was fully recorded and cleared for construction in 6 days, between July 7 and 12. The western half of the site was recorded in 42 hours over a 3-day period from August 8 to 10. The first 4-day recording session was undertaken with one Cyra LIDAR unit and a single operator. However, because of problems of hardware and software interface on the first day of the initial effort in July, for the second phase, I pulled in the equipment and technical expertise from two sources across the country: one from a Cyra representative in New Hampshire and a second instrument and team from 3D Engineering of Florida, permitting two scanners and operator teams in the air and on the ground both day and night for the last 3-day recording effort. A total of 900 metric Rolleimetric images and 600 megabytes of multiple 3D laser-point cloud scans were recorded. The project began construction on schedule without undue delays and costs.

Discussion

The two technologies are not redundant but provide independent processes for remotely recording the context and coordinates of excavated features and

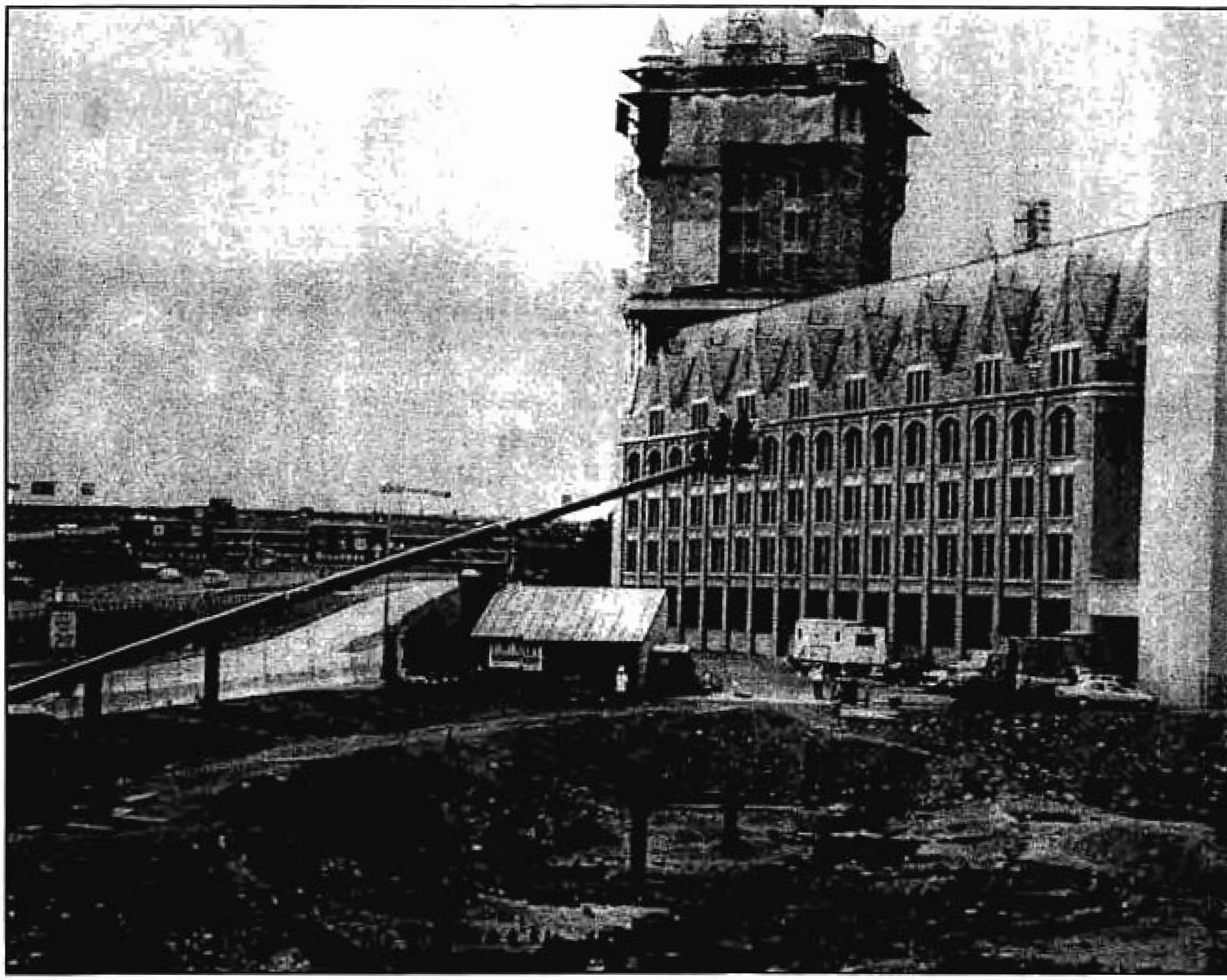

Figure 15.12. Field view of portable LIDAR scanner and technicians suspended over the wooden bulkhead structures.

artifacts. Whereas LIDAR provides dense records of point coordinate information, the single-camera photogrammetry system exemplified by the Rolleimetric camera and software systems provides a long-term visual archive of frozen provenience and metric information. Images can be retrieved and reanalyzed via the computer coordinate software components to extract specific points and dimensions of any visible objects or surfaces. The high-resolution, metrically precise, medium-format images produced by the single-camera photogrammetry can be enlarged and studied in detail to reveal minute elements and surface details of exposed archaeological features. What may have been exposed but overlooked during excavation can be reevaluated at any time in the future.

The two recording technologies are also complementary. The point-cloud data of the LIDAR scans can be interpolated in the computer into actual coordinates and as an interpolated or triangulated matrix to form a metrically accurate framework or skeleton rendition of the recorded features. These frameworks can be computer processed in varying degrees of resolution from a simple 3D matrix of connected points to a high-resolution computer image, which simulates the form and surface details of the objects or structures being recorded. But this computer-processed LIDAR imagery is not yet photo-realistic in its detail (Figures 15.13 and 15.14).

In essence, the high-speed LIDAR produces a metrically accurate point cloud or skeleton record of the

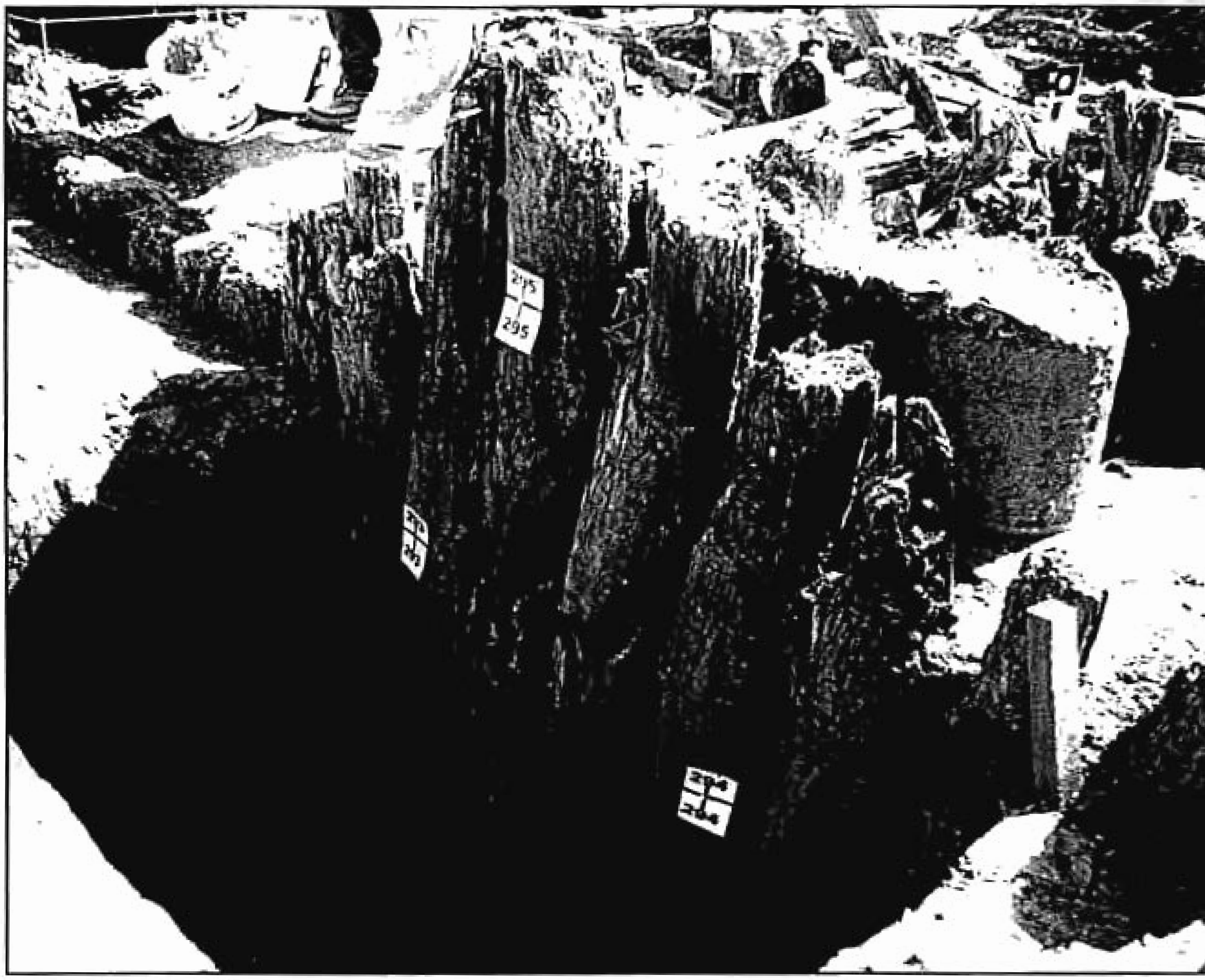

Figure 15.13. Detail of one section of the vertical eighteenth-century wooden log bulkhead with control targets for reference to laser-radar scans. An example of a laser-radar scan may be seen in Figure 15.14.

archaeological surfaces and structural elements (Figure 15.14). In contrast, the high-resolution color imagery produced by the Rolleimetric single-camera photogrammetry, produces a precise, metrically accurate, high-resolution color image of the surface, or skin, of what is being recorded (Figure 15.13). The current technological challenge is to seamlessly blend the two, to fit the photogrammetric skin over the skeleton of precise LIDAR coordinate records.

Currently available software can readily surface-map or laminate digital images onto simple geometric forms. But the ability to precisely match or surface-map the thousands of points that make up an irregular hand-cut wooden form or irregular stone-building element with the minute visual details of a high-resolution metric photograph is still being developed. Current computer systems can produce or simulate the appearance of realistic-looking surface mapping of images over digital frameworks, but the level of precision is at best still crude. The ability to accurately surface-map the 900 metric images of the hundreds of wooden elements recorded in Albany onto the dense 3D point clouds recorded by the LIDAR scanners is still probably 2 to 5 years off.

Conclusion

What are the implications for the future of these recording technologies for archaeological project management and planning? In the first place, it is im-

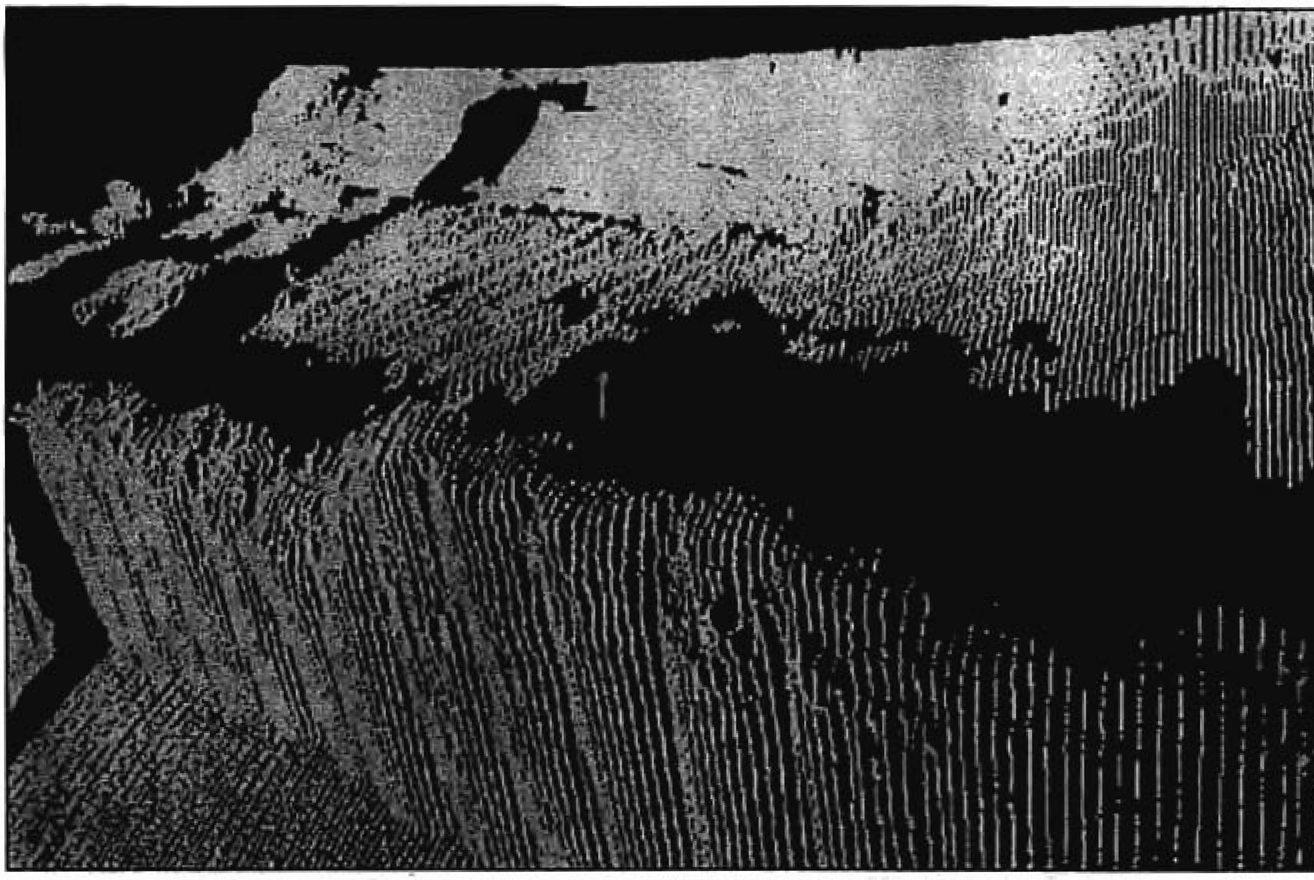

Figure 15.14. A computer "screen shot" of a raw 3D laser-radar scan of vertical wooden bulkhead elements. Each scan line represents thousands of millimeter-precise coordinate points across the surface slice of exposed log elements.

portant to reiterate that these systems are new, still under development, and by no means perfected. Any recommendation for their use is not a slam dunk. Hardware and software are constantly being upgraded. The photogrammetric and laser data sets are generally massive and difficult to process with standard office computer systems, and they require a concerted effort and budget allocation to integrate and control. Nevertheless, the potential exists for this technology to have a significant impact on archaeological excavation and documentation procedures.

From the project management perspective, the speed, flexibility, precision, and near total coverage provided by the LIDAR scanning technology together with high-resolution color imagery of single camera photogrammetry gives the profession the ability rapidly to document unexpected finds or sites difficult to access. The availability of the current generation of powerful portable computers, in turn, gives the archaeologist in the field the means to transform this cloud of scanned point records into a database of recorded site-specific artifact provenience and feature coordinate points. Instead of 300 readings per day made possible beginning in the mid-1970s with the advent of computerized total-station electronic surveying instruments, this new LIDAR scanner technology in conjunction with computerized photogrammetry provides the field archaeologist with the ability to record literally millions of data points in a matter of hours.

The implications of these emerging technologies are profound from legal, policy, scientific, and public interpretative perspectives. For the archaeologist and planner faced with the challenge of needing to record a complex archaeological discovery unexpectedly encountered in the path of ongoing construction, this technology can become a tool of conflict avoidance.

This evolving capability in turn gives both the scientist and the planner the means of responding to unexpected discoveries in a feasible, practicable, and cost-effective manner that serves to reduce or even negate past arguments against doing justice to our dwindling record of unwritten history and precontact evidence. The specter of dire fiscal constraints posed by the popular paradigm of "history versus progress" may no longer hold.

Finally, from the perspective of our ability to create public interpretations, these new recording capabilities also suggest that the field archaeologist will be able to provide the educator and museum curator with almost ready-made visual data sets capable of being transformed into dynamic public interpretative programs in a fraction of the traditional time frame.

As recently demonstrated by the extraordinary public theater installations in Israel, Canada, Europe, and Japan, large-scale photo-realistic interactive and total immersion virtual reality simulations of ancient archaeological sites are now becoming the norm at major national tourist centers around the world. Up to now, these projects have been both costly and time consuming, largely due to the nature of traditional archaeological data recording and rendition. Much of the effort to simulate "walk-through" reconstructions of ancient monuments and sites has involved the often laborious process of transforming traditional manual and paper archaeological field and publication records into computer-compatible formats suitable for rendering into 3D simulated, computer-rendered models. These time and cost factors could change significantly if and when the archaeological community readjusts traditional field strategies to incorporate the newly available computer-compatible digital point-data and image-recording systems.

It is not unreasonable to project that in the near future archaeologists will be able to concurrently record 3D digital records of what they excavate with near total accuracy. Images of excavated structures and features can be reviewed on the computer screen in the field, and any point can be zoomed in to reveal the dimensions, coordinates, surface texture, and accurate color qualities of what is being excavated during, instead of long after, the objects are discovered and/or destroyed. The day may not be too far off when pro-forma archaeological reporting and interpretative efforts will include millimeter-precise virtual reality reconstructions of archaeological sites.

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