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Using 3-D Scanning to Create Virtual Landscapes for Historic Sites

Marion Smeltzer

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USING 3-D SCANNING TO CREATE VIRTUAL
LANDSCAPES FOR HISTORIC SITES

A Thesis

Submitted to the School of Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Master of Arts

Marion Smeltzer

Indiana University of Pennsylvania

December 2016

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Indiana University of Pennsylvania
School of Graduate Studies and Research
Department of Anthropology

We hereby approve the thesis of

Marion Smeltzer

Candidate for the degree of Master of Arts

William J Chadwick, Ph.D.
Associate Professor of Anthropology Advisor

Benjamin Ford, Ph.D.
Associate Professor of Anthropology

Beverly Chiarulli, Ph.D.
Assistant Professor of Anthropology Retired

ACCEPTED

Randy L. Martin, Ph.D.
Dean
School of Graduate Studies and Research

Title: Using 3-D Scanning to Create Virtual Landscapes for Historic Sites.

Author: Marion Smeltzer

Thesis Chair: Dr. William J. Chadwick

Thesis Committee Members: Dr. Benjamin Ford
Dr. Beverly Chiarulli

This project first started as part of an internship when researching and recording structures at the Allegheny Portage Railroad Historic Site (ALPO) using a Leica Scan Station C10 to provide detailed digital records for the National Park Service (NPS). The Allegany Portage Railroad located in Cambria County, Pennsylvania is a National Historic Site and part of the Mainline Canal connecting Philadelphia and Pittsburgh. The use of 3D modeling is a new form of historic property documentation and this document helps illustrate how this technology can assist future archaeologists and historians. Through the 3D scans taken at the site, an opportunity was seen to apply the information gathered from the processed data to utilize it as a way to promote an interest in archaeology and historic preservation by sharing the imaginings on a virtual platform. The processed data taken from the scans were used as the basis for creating realistic reconstructions of the three structures at the historic site and placed them in a virtual landscape. This new material provides an additional resource of baseline information for others interested in the historical landmark by showcasing a bygone era through the virtual platform.

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I have so many people to thank for their time and dedication in helping me through my Masters (something I never thought I would complete). First and foremost, I would like to thank my former advisor Dr. Beverly Chiarulli. You gave me challenge's and saw my potential when I couldn't see it in myself, and I gained so much more by trying to follow in your footsteps. Thank you, it has been an exciting adventure.

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CHAPTER I

INTRODUCTION

The Allegheny Portage Railroad (APPR) in Cambria County, Pennsylvania is a National Park Service (NPS) Historic Site. The railroad system was constructed as a segment of the Mainline Canal by the State of Pennsylvania who used numerous local contractors through the Allegheny Mountains in central Pennsylvania; it was opened in 1834, and was abandoned by the Commonwealth of Pennsylvania in 1855. The site is located along the Allegheny Portage Incline Trail at the summit and to the east side of the Allegheny Mountains. During its time of use, it served as a vital part of the Commonwealth's canal and railroad transportation system (Brown 1984). With the completion of the direct route between Philadelphia and Pittsburg it was later referred to as "The finishing piece of the Pennsylvania Mainline Canal" (ALPO, 2013). The route provided a faster means of transporting raw materials and manufactured goods from east to west through a series of inclined plans and a canal system. The Allegheny Portage Railroad and the canal system were in operation for 20 years, from 1834-1854, until the transportation system was discontinued by the State of Pennsylvania. (ALPO, 2013).

According to an article written by Janiskee "Today, the Allegheny Portage Railroad National Historical Site preserves a section of this early engineering accomplishment that used a series of ten inclines to pull canal boats over the Allegheny Mountains along the 36-mile-long corridor on the railroad's historic route attracting 123,00 visitors per year." (Janiskee, 2008). The historic site, authorized by Congress in 1964, preserves a portion of the Portage Railroad (Fiero, 1983). Situated on 1,296 acres, the National Historical Site consists of the "Summit Level Visitor Center, the Lemon House, Engine House #6 and Exhibit Shelter, the Skew Arch Bridge, picnic areas, and several hiking trails" (ALPO, 2013). The grounds are preserved and maintained by

theNational Park Service (Figure 1). It serves as an essential learning environment for the community’s early rail and canal transportation system (ALPO, 2013).

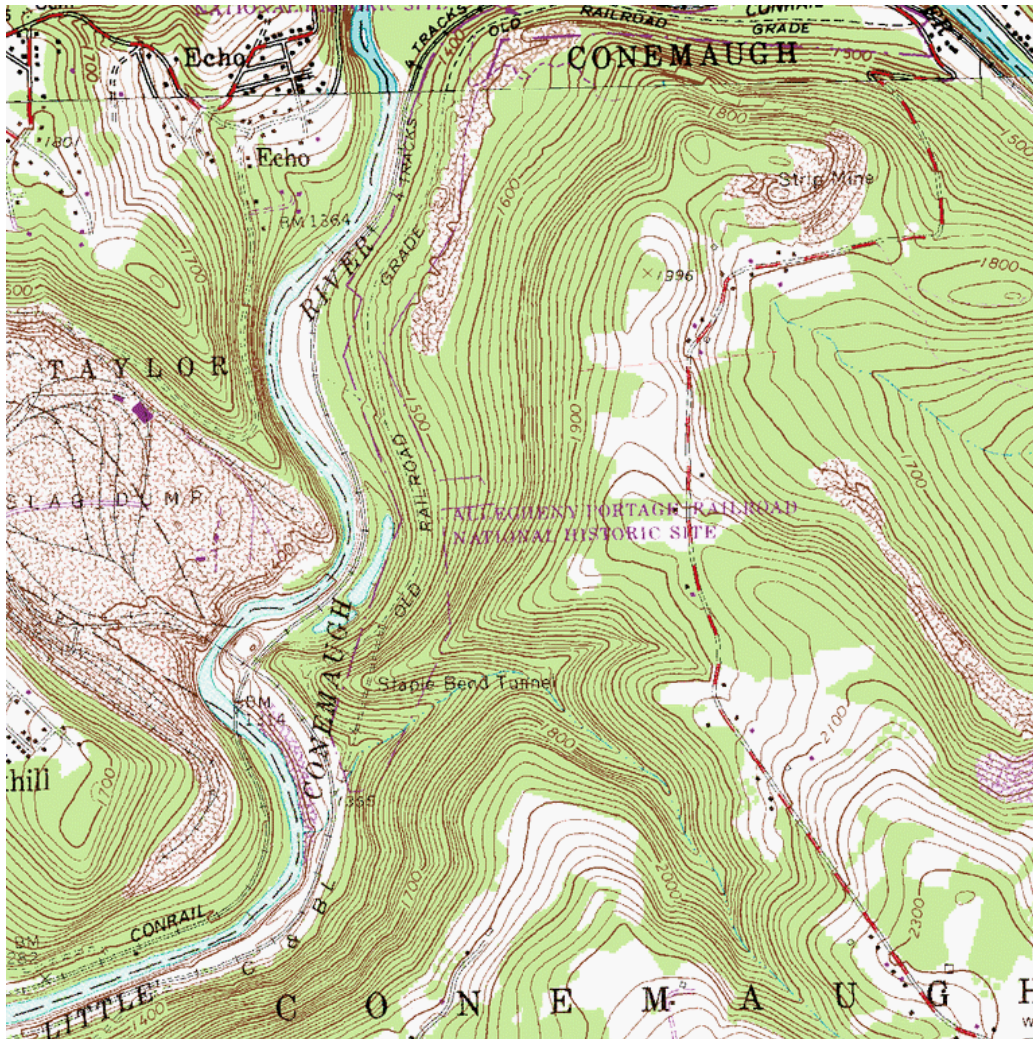


Figure 1. Topographic map of Allegheny Portage Railroad National Historic Site (Courtesy of topoquest)

In the summer of 2013, a Leica Scan Station C10 was used to record three of the historic buildings and structures associated with the Allegheny Portage Railroad Historic Site: the Skew Arch Bridge, Engine House #6 Exhibit Shelter, and the Lemon House. The main scope of this project was to use 3-D scans to make a record of the structures at the Incline and Level 6 using the Leica Scan Station C10, and to process the data from the scans through the Cyclone Point Cloud Processing software to provide more detailed maps for the NPS. These data were used as

the basis for creating 3-D reconstructions of the structures, and place them on a virtual landscape. This form of historic property documentation illustrates how 3D technology can assist future archaeologists and historians. The information gathered from the Laser scanner also provides an additional resource of baseline information for the National Park Service to more effectively monitor how the structures are affected by environmental factors through time.

In addition to providing documentation for the cultural resources on the site, the reconstructed 3-D models can also serve as an educational tool and promote public interest in the Allegheny Portage Railroad National Historic landmark. The virtual environment created through the 3-D models was designed and landscaped to replicate the era of the 1800s, giving virtual visitors a sense of traveling back in time to tour the environment and contents.

The following chapters describe the concept of this project, the methodology used in this project, and the conclusions that resulted. Chapter II describes what 3-D scanning is, how the process of 3-D scanning works and where 3-D scanning has been used previously in various environments and locations. Chapter III describes the history of the Allegheny Portage Railroad and the remaining historical structures located on the grounds. The methods section in Chapter IV, gives a brief explanation of operational methods followed by what was done in the field with the locations and intervals of the scanning procedure and data processing. Chapter V describes the results of the scans, important factors to consider in future scanning projects, and what the images revealed from a 3-D perspective. Chapter VI, Conclusions, summarizes the results and discusses how the National Park Service and other agencies can use this technology for preservation.

CHAPTER II
THREE-DIMENSIONAL (3-D) SCANNING

What is 3-D Scanning?

Three-dimensional scanning is sometimes also referred to as laser scanning or High Definition Survey (HDS). “Although laser scanners have been available for over ten years, their applicability as productive and competitive survey tools have just emerged in the last three years” (Frei, 2004 pg. 262). As an alternative to traditional documentation, High Definition Surveying allows users to quickly digitize real-world settings into precision 3-D renderings. The main advantage of 3-D scanning is the scanner unit’s ability to rapidly record the interior or exterior, man-made or natural structure or area within the scanner’s area of view. Three-dimensional scanning enables users to traverse, resection or use scan targets to deal with site logistics. The scans have “a full 360° x 270° field-of-view, high accuracy, long range (300m at 90% reflectivity), and high scan speed (50k points/second)” (Leica, 2013) (Figure 2).

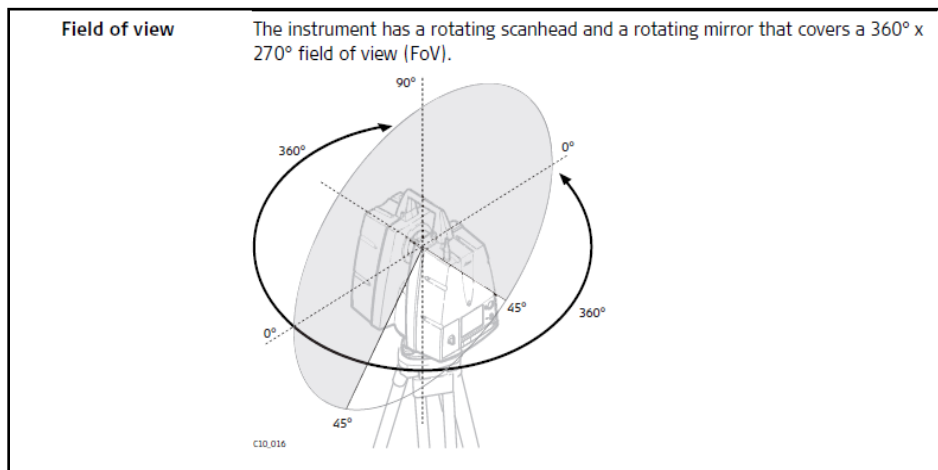


Figure 2: 3-D Scanner’s field of view. (Leica Scan Station C10 System Field Manual 2010)

The scans are used to carefully observe parts of an object or landscape in order to detect some feature to create an image. The scans, which include pictures, are captured quickly in vast 3-D detail without the need to disrupt or make contact with any of the structures or the environment.

In other words, 3-D laser scanning can be used to capture a physical object's exact size and shape and record this information as a digital 3-D representation by scanning structures at regular intervals. The data collected through the scans can also provide important information about environmental factors, including ground disturbances that may damage sites (Apex, 2013). Scans can encompass entire landscapes in which natural elements such as trees, culverts, or building frontages are included. Additionally, visual models can be reconstructed using 3-D modeling elements for project determinations, preservation or information sharing.

How Does 3-D Scanning Work?

The technology behind High Definition Scanning consists of a mirror within the scanner unit “that deflects the beam towards the scan area, and an optical receiver which detects the laser pulse and reflects it back to the scanner from the object” (Truepoint, 2013).

According to the description from Geomagic:

“Laser pulse-based scanners, also known as time-of-flight scanners, are based on a very simple concept: the speed of light is known very precisely, so if we know how long a laser takes to reach an object and reflect back to a sensor, we know how far away that object is. These systems use circuitry that is accurate to picoseconds to measure the time it takes for millions of pulses of the laser to return to the sensor, and calculates a distance. By rotating the laser and sensor

(usually via a mirror), the scanner can scan up to a full 360 degrees around itself”
(Geomagic, 2014).

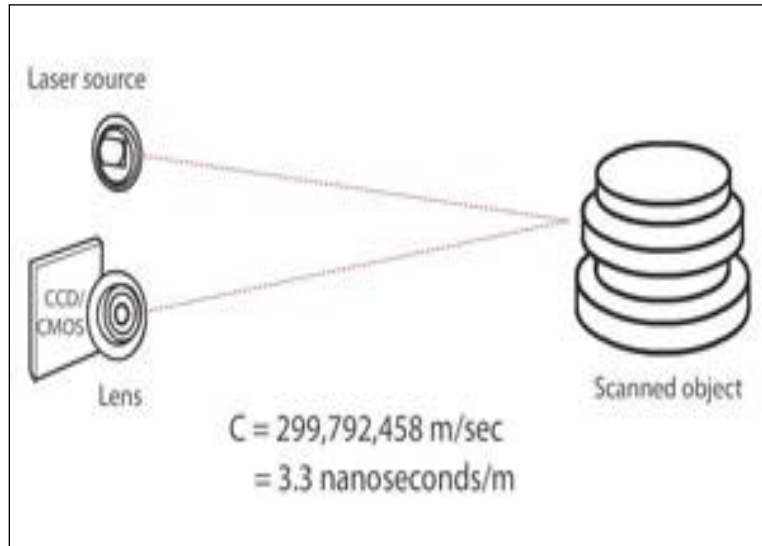


Figure 3: View of Laser Pulse-based 3-D Scanners (Geomagic,2014)

In other words, a narrow eye-safe laser beam of pulsed laser light moves across an object such as a structure or bridge, gathering millions of measurements points in a matter of minutes. Each point of the surface touched by the laser beam is captured by a camera incorporated into the scanner unit (Geomagic, 2014).

The points have a unique X, Y, and Z, geometric value that is displayed on a computer screen in the form of a point cloud database, which closely resembles a 3-D model. With millimeter level accuracy, multiple scan locations are then combined to create 3-D point clouds, which are the points on the surface of an object. This then produces a series of points known as a “point cloud” for a data file, which represents a set of points the device has measured. This collected information is recorded in the memory of the computer controlling the scanner unit, providing detailed digital archive data. The data can be exported and used in a variety of

disciplines and applications such as virtual walkthroughs, TruViews (software viewing program), interactive 3-D models, reconstruction plans, critical renovation plans, preservation and conservation management, archaeological research, and Building Information Modeling (BIM), to name just a few of the possible uses for HDS. (Fenstermaker, 2014)

Where Has 3-D Scanning been Applied?

With the constant threat of natural disasters, human destruction, and limited budgets, a digital archive of 3-D scans of historical architecture, landscapes, or artifacts may prove to be one way of protecting some of our archaeological and historical cultural resources. Three-dimensional scanning has been demonstrated to be valuable to agencies and organizations involved in preservation efforts, especially for resources that are now, or may someday be at risk.

For instance, in an article titled “Project Captures Orlando History in 3-D Virtual Reality,” Walter Pacheco in 2011, describes a renovation in Orlando, Florida at the historic Sligh Boulevard train station. The train station was built in 1926 and was still being used by Amtrak. Plans were being made to expand services with SunRail, a commuter rail system under construction, after upgrades to the station were completed.

Thomas McPeck, an architect and Assistant Professor from the University of Central Florida, organized the project and noted that urban-design objectives call for 3-D modeling, and that “the city would be among the pioneering few to tackle the concept”. Pacheco, W. (2011) Project partners included Greg Richards of Lake Mary, Florida-based FARO Technologies, who helped in renovation and preservation efforts of the historic structure, before any changes were made to the building's foundation. By using laser scanner technology, Richards was able to scan

the interior and exterior of nearly 6,500 square feet in about a day and created an accurate 3-D representation of the train station.

The article goes on to further explain:

“Orlando officials hope to make the 3-D renderings of the stucco Spanish Mission Revival style building available on the Internet for the public to appreciate the technology and a small portion of Orlando history. It is believed that these three-dimensional images of historic buildings may even help the region’s tourism and real-estate industries” (Pacheco, 2011, Page A-1).



Figure 4: Sligh Boulevard Train Station in Orlando, Florida
(Courtesy of Orlando Sentinel)

According to Griffiths (2014) article the author mentions:

In November of 2013, the Smithsonian Museum announced plans to use technology to 3-D scan its artifacts and share them by printing them in 3-D and placing them online (Griffiths, 2014). Museum staff have scanned collections and made the 3-D models accessible to many world museums, including various exhibits that were recreated digitally and turned into 3-D models (Griffiths, 2014). The 3-D “scans are. being made available on the Smithsonian's

website, where visitors can examine them from all angles using the Smithsonian 3-D Explorer tool” that is available on any web browser (Griffiths, 2014).

Adam Metello, a 3-D digitization program officer at the museum stated that "the vast majority of the United States, let alone the rest of the world, do not get to actually come to our museums. The 3-D scanning technology has multiple uses and by digitizing [exhibits] in this way, we can share our collections almost as if people could come to the museums themselves" (Griffiths, 2014).

The Smithsonian's Vincent Rossi stated, "This also represents a completely new way of documenting archaeological or paleontological sites. Rossi predicts that [the practice of] 3-D scanning a discovery before it's removed will become standard practice, preserving its record and allowing scientists around the world to carry out research remotely. We can record a moment in time, and we will have a very accurate 3-D record" (Griffiths, 2014).



Figure 5: 3-D Model of Woolly Mammoth from Smithsonian Museum
(Courtesy of Sarah Griffiths)

In July 2013, Matteo Luccio wrote an article titled “Surveying Cultural Heritage,” in *Professional Surveyors*, which highlighted how an interdisciplinary team using 3-D laser scanning and photogrammetry to model the sites at high resolution could help preserve and manage cultural heritage sites (Luccio, 2013).

In the article, Luccio (2013) stated that CyArk, a nonprofit organization, and members of the Scottish Ten team “used laser scanners to generate highly accurate 3-D models of buildings and monuments around the world” (Luccio, 2013 Page 10). The project, which started in 2009, has since completed the work on three sites: “Mount Rushmore National Memorial in South Dakota, the Rani ki Vav Stepwell in India, and the Eastern Qing Tombs in China” (Luccio, 2013 Page 10).

Other information referring to the CyArk project mentioned Justin Barton from the CyArk team stated that “the sites have unique conservation issues.’ For example, at Mount Rushmore they are concerned with monitoring the rock blocks that make up the mountain, so providing engineering-grade information can help with that.” (Luccio, 2013 Page 12)

The article explains how the information can also be used to create models and animations that help visitors understand the sites better, and give them virtual access to areas they cannot see. In 2012, with some of the highlights from the information collected by the CyArk, “the National Park Service unveiled an online virtual tour of Mount Rushmore and the Hall of Records”. (The Scottish Ten, 2016)

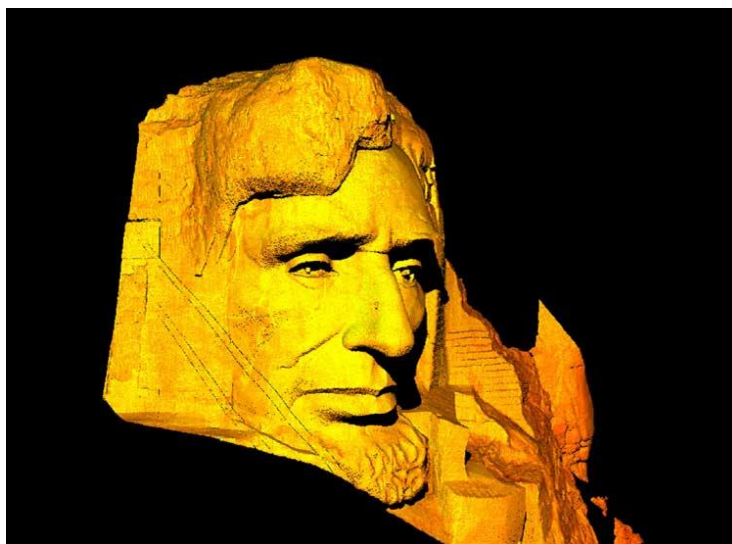


Figure 6: 3-D Model from scan taken at Mt. Rushmore in South Dakota (Courtesy of CyArk/CDDV)

The project area of this thesis is the Allegheny Portage Railroad (APRR) located in Cambria County, Pennsylvania. During the months of July and August of 2013, under the supervision of Nancy Smith, Cultural Resource Program Manager/Curator at the Allegheny Portage Railroad Historic site, a series of 3-D survey scans were done on the existing historical structures located on the grounds.

Like the pioneering CyArk digital preservation project at Mount Rushmore National Memorial, the information from the laser scans taken at the Allegheny Portage Railroad National Historic site are the first 3D scans in Cambria County for historic preservation purposes. The digital archive will help the National Park Service to better preserve, protect, and interpret its historic resources using the latest technology, and will make the resources more accessible for detailed architectural studies and analysis.

The digitally captured images and visualizations can also be applied to modeling, archiving, public dissemination and virtual educational platforms. The development of new

educational materials and on-line learning, can encourage a new generation of students to learn about the area's history in new and engaging ways.

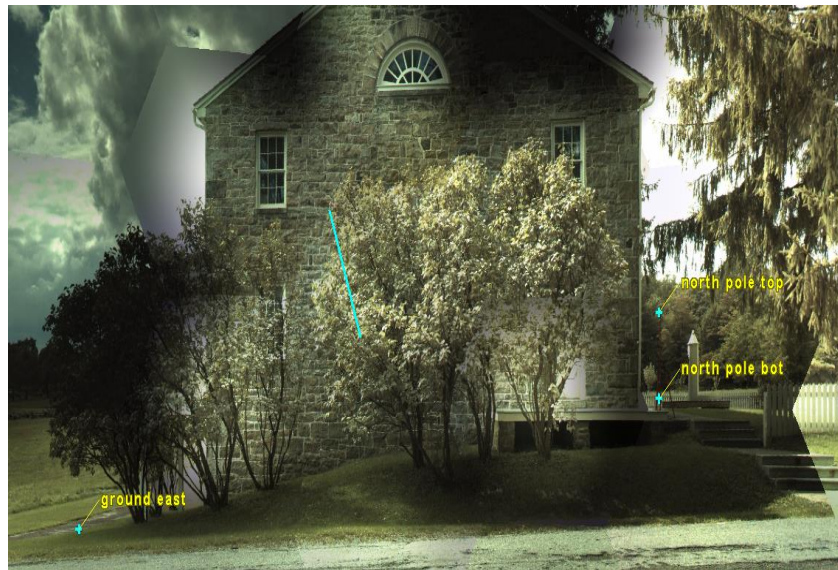


Figure 7: 3-D scanned image of Lemon House at APRR (2013)

CHAPTER III

THE ALLEGHENY PORTAGE RAILROAD

During the mid-1820s, Pennsylvania initiated and supported an enormous program of infrastructure improvements that included the construction of canals, turnpikes, and railroads (Toogood, 1973). In 1826, the Pennsylvania legislature passed an act authorizing the construction of a cross-state canal linking Philadelphia to Pittsburgh. Pennsylvania's canal builders were faced with the challenging problem of how to provide a passage across the natural barrier formed by the Allegheny Mountains. Pennsylvania's canal commissioners believed they had found a solution to the problem by constructing a series of ten inclined planes, five on each side of the highest ridge of the mountain, and excavating a tunnel that connected to the Pennsylvania Canal. This “Portage Railroad” was 36 miles long (Fritz & Berle, 1992). An “incline system was used because the locomotives of this time did not have the power to pull the cars up steep mountains” (NPS, 2013).

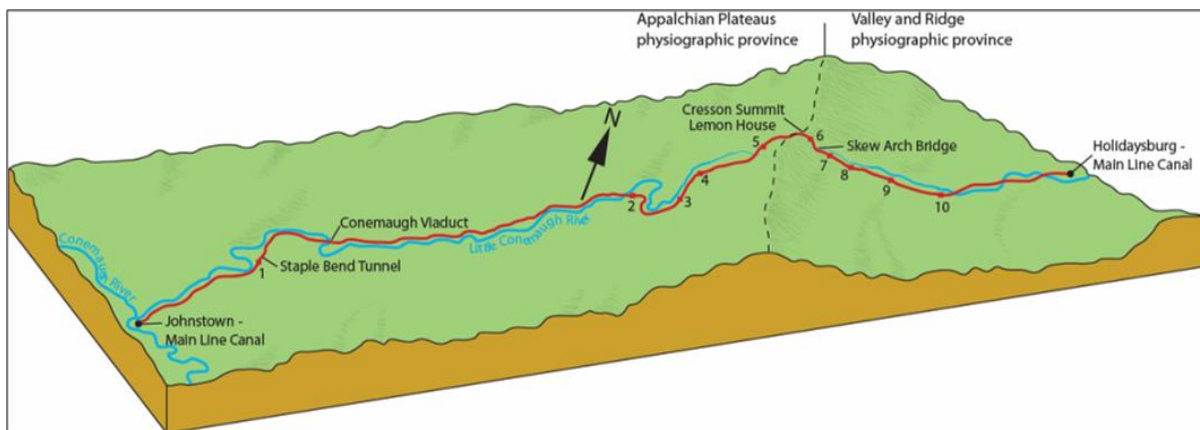


Figure 8. Map showing ten incline planes of the Allegheny Portage Railroad (Courtesy of ALPO Geologic Resource Evaluation Report)

On March 4, 1828, the Pennsylvania legislature passed an act that led to the birth of the Pennsylvania Railroad: "An Act Relative to the Pennsylvania canal, and to provide for the commencement of a rail road, to be constructed at the expense of the state, and to be styled the Pennsylvania rail road." The Portage Railroad was abandoned in 1857 (Rotenstein, 1997).

Historic Structures at the Allegheny Portage Railroad

Today the Allegheny Portage Railroad is a National Park Service Historic Site. Under the direction of the National Park Service, the site preserves and maintains the traces of the first rail-road crossing the Allegheny Mountains, and three historic structures at the Incline and Level 6 which include the Lemon House, Engine House #6 and Exhibit Shelter, and the Skew Arch Bridge.

The Lemon House

Samuel Lemon, a local business man, first built a small log tavern at the top of the Allegheny Front in 1828 to take advantage of the Northern Turnpike traffic and the area's water and coal resources. Mr. Lemon replaced the log building with a larger one in anticipation of the opening of the Portage railroad, although there was no certain date for the construction (Brown, 1983).

Also referred to as the Summit House, the Lemon House, built with its front doors facing the railroad and its back to the turnpike, served as a stopover point and occasional hotel for railroad travelers. Lemon's tavern was constructed to reflect the late Federal Style (1820-1830) which at the time was fashionable in Philadelphia. Philadelphia was the leading center of art and architecture in America throughout the nineteenth century (Toogood, 1980). The three-story

stone structure and its property saw many owners and many renovations, and served other purposes over the years (Levy, 1969).

In 1907, the property was sold by the remaining Lemon family members for the sum of \$9,000 to Joseph and Margret Gray who ran it as a dairy farm. It was then sold to W.J. Sherry in the same year. In 1912, the property was sold to J. C. Weston who also used it as a dairy farm; his son later inherited it (Levy, 1969). The property was then leased to James and Zella Gailey from 1943 to 1954. The Gailey's chose to use the main part of the house as living quarters and provided rooms on the second floor for overnight travelers. Early in the 1950's, Byron Roberts purchased the property with the intention of renovating it to its former appearance, while modernizing a section of the house for living space (Toogood, 1980). The last known owner, Mrs. Roberts, sold the property to the National Park Service in 1966 (Levy, 1969).

While the home was in private hands, past renovations obscured some of the architectural details. "Out-buildings, including the privy or necessary house, which were certain to have existed in the 1840s were never located" (NPS, 2013). There are no known archived plans or figures of the original layout of the Lemon House and it is difficult to establish the actual size of the original interior rooms. However, a hand-drawn floor plan of the first floor was submitted on Page 4 of the 1994 Lemon House Historic Furnishings report, illustrating the likely layout of the rooms and doorways (Brown, 1994). Interestingly, the floor plan did not include the extension located off the west wall in the area marked Double Dining Room. "Much of the recent restoration of the Lemon House was started on archeological research. The second floor, which would have been family quarters, now contains the NPS library and office space for the staff. The Lemon House is generally open for visitors from 9 a.m. to 5 p.m. daily" (NPS, 2013).

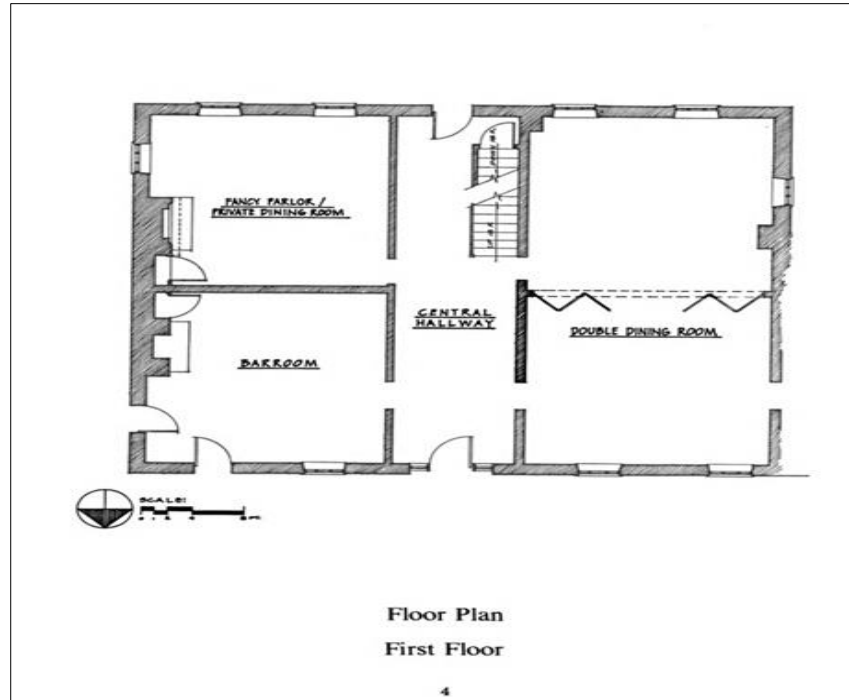


Figure 9: Drawing of First Floor Plan of Lemon House (Courtesy of NPS, Harpers Ferry Center)

Engine House #6

Situated a short distance away from the Lemon House is Engine House #6. Construction of the Engine House took place after “James Stackpole, William Woodburn, and H. Simson won a contract to build an engine house and road shed at the head of the plane [Incline 6], and a road shed at the foot of the plane together with all the masonry excavation and connected with the same” (Brown, 1984). The Allegheny Portage Railroad business journal provided the following information about the construction of the railroad, including the work that was done at the Engine House at Plane 6 as follows (Brown, 1984).

860.77 c. yards Extended at head of plane

273.33 Perches Masonry in wall supporting engine and machinery

46.08 Perches Masonry in Foundation walls at head of Plane

12.00 Perches Masonry in Foundation walls at foot of plane
57.28 c. yards Excavated at foot of plane
303.00 ft. lineal in frame supporting and connecting with machinery
 Digging and Walling well 15 ft. deep
 Building Engine House and Shed
 Building Shed at foot of plane
234.00 Shelves hung and fitted
 Hanging and fitting large shelves at foot of plane
633.33 ft. lineal frame work connected with it
 Furnishing materials and connecting movable car at head
 Work not included in contract
 Digging and boring well 106.25 ft.
 Boring 14.85 ft.

“Work on the Engine House at the head of Incline 6 was completed by May 30, 1834. In 1852 the structure blew up killing four people, and a second Engine House was built” (NPS, 2013). According to their pamphlet, “After the railroad was abandoned the Engine House was converted into a barn. The foundations were recycled by the Pennsylvania Railroad for use in other buildings. Over time, many other changes occurred but not all were recorded. The current shelter helps to preserve the remains of Engine House #6” (NPS, 2013).

Now referred to as Engine House 6 Exhibit Shelter, “over half of the building contains a life-sized reproduction of the machinery that would have been needed to hoist canal boats and train cars over Inclined Plane 6” (NPS, 2013). “This includes a stationary engine as well as the

gears, brakes, and assorted levers that kept the tow-rope in motion. The building itself is the same shape as the original Engine House but it is larger to protect the original foundations” (NPS, 2013) “Sections of the original foundation can be seen through the metal grating that also serves as flooring in the shelter” (NPS, 2013). “At the east side of the Engine House Exhibit Shelter is a platform that permits visitors to look down the length of Incline 6 to the Skew Arch Bridge” (NPS, 2013).



Figure 10: Remains of Engine House 6 Foundation Stones (Courtesy of NPS)

The Skew Arch Bridge

The National Park Service web site referenced The Skew Arch Bridge as “located near the Lemon House and Engine House #6 Exhibit Shelter at the Allegheny Portage Railroad National Historic Site” (NPS, 2013). “The structure was the only road bridge built along the portage” (NPS, 2013). On July 15, 1832, “J. Fenlon, A. and J. Darlin, and R. Kininmouth won the contract to build ...A Stone Bridge which will be required for the passage of the Turnpike road over the Rail Way on Section No. 36 of the Portage... The bridge was to be built according to specifications attached to and considered part of the contract” (NPS, 2013).

According to authors Baumgardner & Hoenstine “The measurement of the skew arch is 60 feet 5 inches long on the south elevation, 54 feet 11 inches long on the north elevation, and 22 feet 2 inches high. Broken stone and stone sleepers taken from a section of the railroad were perched, fitted, and laid diagonally by hand without mortar. The top of the bridge was not tilted but the arch’s imposts were offset and constructed directly across from each other. Rectangular stones were then cut into an L shape and placed to reinforce the external corners of the pilasters and walls” (Baumgardner & Hoenstine, 1952).

“The bridge design was changed in 1833 to accommodate a bend in the Huntington, Cambria and Indiana Turnpike road, hence the skewed arch. The construction journal noted on May 21, 1833, the expense of “Taking up & relaying masonry in consequence of alteration in place.” (NPS, 2013).

The Skew Arch Bridge served as a highway bridge until 1922, almost 70 years after the Old Portage Railroad discontinued operations. The Blair County Historical Society erected a monument in 1928 to commemorate the bridge it reads:

THIS SKEW ARCH BUILT IN 1832-33 TO CARRY THE
HUNTINGDON-BLAIRSVILLE SECTION OF THE MODERN
TURNPIKE OVER INCLINED PLANE NO. 6 OF THE ALLEGHENY
PORTAGE RAILROAD

In 1966, the National Park Service listed the Allegheny Portage Railroad National Historic Site on the National Register of Historic Places (NPS, 1993). At that time, the Skew Arch Bridge was also nominated to be listed on the Register. “In 1979, the bridge was stabilized and repaired. Nearly the entire exterior has been repointed. Limited sealing was done and some of the facade was mortared” (NPS, 2013).

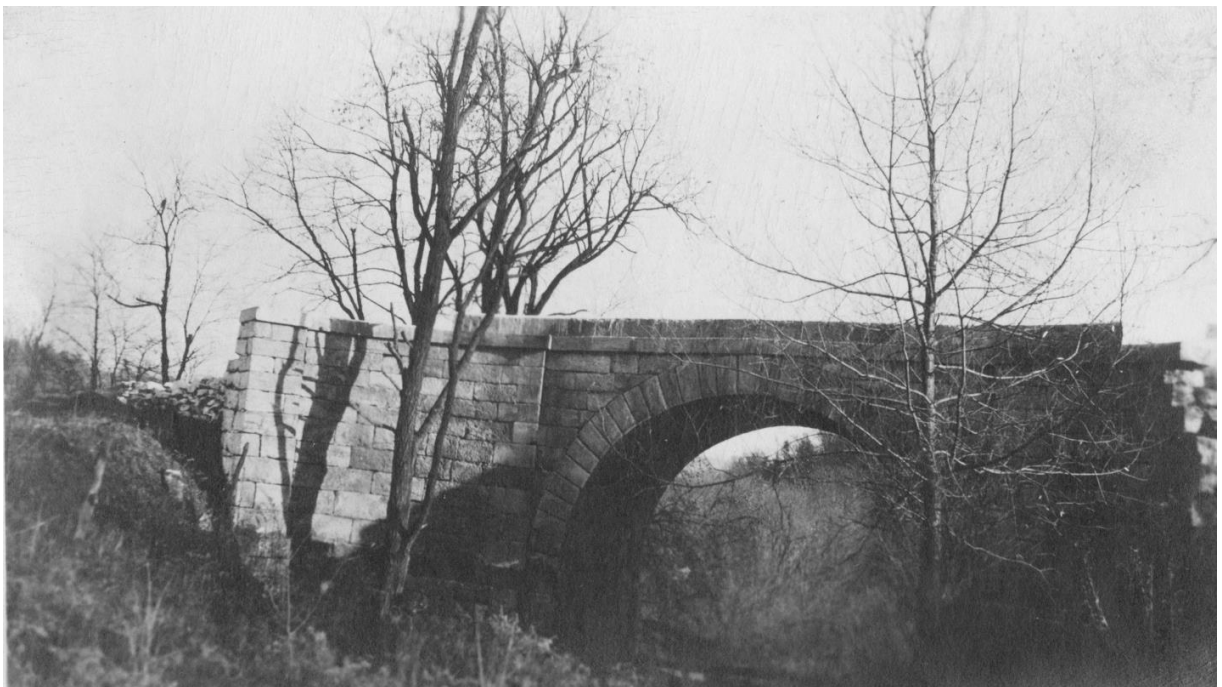


Figure 11: Skew Arch Bridge (Courtesy of the Pennsylvania State Archives)

CHAPTER IV

METHODS

This methods chapter is divided into two sections. The first section describes the basic method of how the scanner unit was set up and operated the with accessories to perform a small test scan. The second section, called field methods, gives a more in depth description of the machinery and parts, detailing how they were used during the process while taking the scans during the project.

System Operation Methods

In order to acquire the results needed, researchers must first determine the location that is to be scanned. To become familiar with the setup of the actual machinery and all the needed additions, a room free of all hanging obstructions would serve the purpose.

Locate a spot in the room where you can visually see a large portion of the area (by just turning your head from one side to the other.) Remove the large yellow tripod from the case and adjust the legs accordingly to insure it is even and at a comfortable height to operate. Make sure all screws at the bottom of the legs are tightened to ensure stability, then remove the Leica C10 scanner from its case and place it on the tripod and secure it with the central larger screw to lock it in place. At this point it is extremely important to make sure the instrument is level before it is powered on to prevent scanning inaccuracies. To ensure the instrument is level on the tripod, the foot screws can be adjusted in either direction on the scanner unit, and the level will be verified by the level indication bubble on the scanner.

Once the scanner unit is set, locate desired target areas within your view and choose which target types: pole or magnet targets, would best serve the purpose for your scan. For a

general practice only two to three targets are needed. With the targets now in place return to the scanner and turn it on. The welcome screen appears first, followed by the main menu.

At the main menu, six icons are displayed indicating the available options. With the stylus pen from the scanner unit tap Manage, then Projects, then New. At this screen, name your project using the stylus pen on the keyboard shown on the screen and then press enter. Return to the main screen to the scan icon. Tap the Scan Icon and continue. Tap on the “T field of view” then “Quick View” and then “Set Targets.’ At the set targets screen, with the stylus pen tap on the target type: exp: pole top or pole bottom and give it a name then hit enter. On the same screen tap the section that says “Find Target” tap enter (Pick T) and make sure the icon goes from blue to red, after the target id found hit enter. All targets placed in the area for the scan must be recorded in the same manner. When all the targets are recorded tap Continue, then Scan, and Scan with Images. If an additional scan is needed and targets are moved, they need to be recorded and renamed before proceeding. This also applies if moving the unit to a new location, and/or adding additional targets.

Field Methods

In June of 2013, arrangements were made with Nancy Smith, Cultural Resource Program Manager and Curator at the Allegheny Portage Railroad (APRR), to tour the historic structures located at Incline and Level 6. The Skew Arch Bridge, Engine House 6 and the Lemon House were evaluated.

The current ground conditions and access to all sides of the structures would play a key role in determining the sequence in which scans were taken. It was decided that the Skew Arch

Bridge would be scanned first, because it was the farthest away from the others; then the Engine House followed by the Lemon House would be scanned last. Several locations were evaluated during the tour of the structures, marking ideal spots for positioning the scanning equipment with orange survey tape and flags.



Figure 12: Image of evaluation of grounds in the immediate area of the Skew Arch Bridge.

Scanning the Skew Arch Bridge

On July 24, 2013, scanning began at the Skew Arch Bridge using the Leica Scanstation C10. Temporary orange tape markers and flags were first removed from the area. Since the east side of the bridge was very wet and soggy, because of blocked drainage, the maintenance staff from the APRR carried the needed equipment down the embankment and bridge opening, bringing several carpeted rubber stabilizing pads for use in the waterlogged area. Once arranged on the ground, the pads provided a stable base for the scan station unit and the tripod during the

scanning process. Any movement of the tripod, during the course of the scan, negates the scan results.

Scanning of the bridge began at the back facing Route 22 East. Each location of the Leica C10 was recorded as a station. Station 01, was the first position for the Skew Arch Bridge. The scanner unit tripod was arranged on the pads at the estimated center point of the bridges' arch. The legs of the tripod were adjusted to the operator's desired height and then the tripod was leveled using a small tubular spirit level. This type of level is designed to indicate whether a surface is horizontal (level) or vertical (plumb) by centering a bubble in a glass tube. The Leica C10 scanner was placed on the top of the tripod, by the tribrach, a plate used to attach a surveying instrument located at the bottom of the scan station. It was secured in place with the tribrach's locking knob located on the tripod. After locking the scanner unit into the tripod, it was leveled using the instrument's circular level, located at the bottom of the scan station, to center the bubble. If not leveled using the tribrach or the instrument's circular level, the scanner would not have powered up properly or scanned accurately. Once the scanner was leveled, two batteries were inserted on the side compartments of the scanner, and it was turned on.

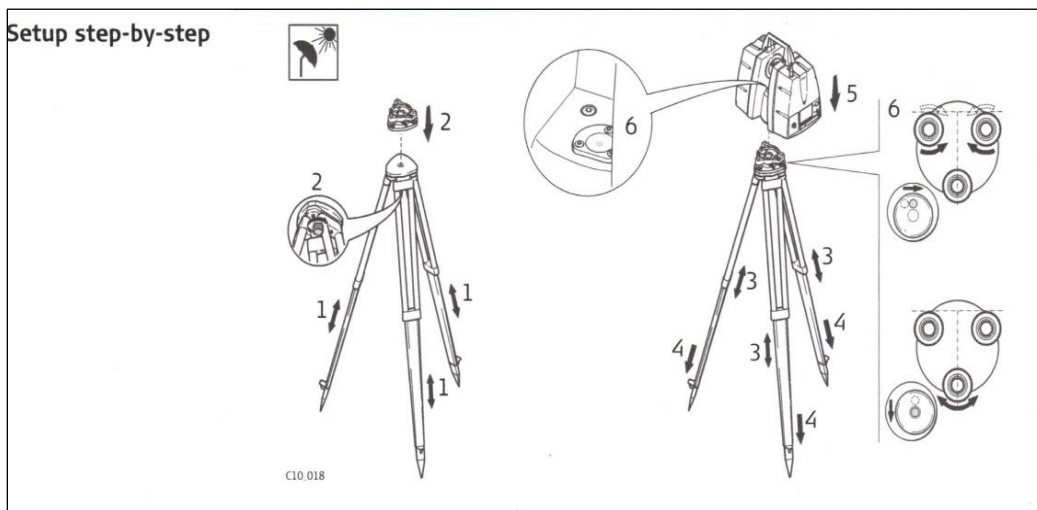


Figure 13: Illustration of set-up process for scanner unit and tripod.
(Leica Scan Station C10 System Field Manual 2010)

Seven HDS scanner targets were assembled and positioned within the scan station's field of view. A target is the high-definition survey equivalent of a prism or reflector that is used to register the point cloud data for each scan. Targets are usually flat surfaces with patterns or spheres and can be arranged as singular or on a twin-target pole system, meaning that one target is on the top of the pole and the other near the bottom of the pole. Targets are used to provide control points so that each scan can be correlated to the previous and next scans. Without them scans cannot be matched up. "Targets allow for accurate geo-referencing of scans to known control points and are useful as a distance-related reference" (Jacobs, 2004). However, due to the size of the structures in this project, it was necessary to move some targets for each of the recorded stations.

The seven targets used for the first scan, referred to as Station 01, consisted of three twin-target poles and one 6-inch sphere target. Each target, whether single or dual, was given a unique ID for reference. The targets and location for Station 1 were recorded as; Target 1: SA1 Top and Target 2: SA1 Bot. The Targets 1 and 2 were on a twin-target pole positioned near the far left corner of the bridge. Target 3: Hill1 Top and Target 4: Hill1 Bot were on a twin-target pole positioned on the embankment near the front of the bridge and visible through the bridges' arch. Target 5: Arch, was a singular sphere target placed on the estimated center point of the bridge top above the arch. Target 6: SA2 Top and target 7: SA2 Bot, were on a twin-target pole positioned near the far right corner of the bridge.



Figure 14: Image showing center target locations for Station 01 Skew Arch Bridge.

With the scanner targets assembled, positioned, and logged onto a note pad using individual names, we went to the next step. A written set of instructions, provided by Leica, were used as a quick reference on how to operate the equipment and proceed to the scanning process. The instructions for the flow order, are defined in more detail in the Leica Scan Station C10 System Field Manual (Leica Geosystems, 2010).

All seven targets used in the Station 01 set-up were recorded (Appendix 1) and stored successfully in the Target File. The complete process of recording all seven targets, took less than ten minutes for the set-up. The next step was to start the scan. The entire scan can usually be acquired in less than ten minutes, depending on the size of the area being scanned. For the Skew Arch Bridge Station 01, the area was scanned in less than five minutes.

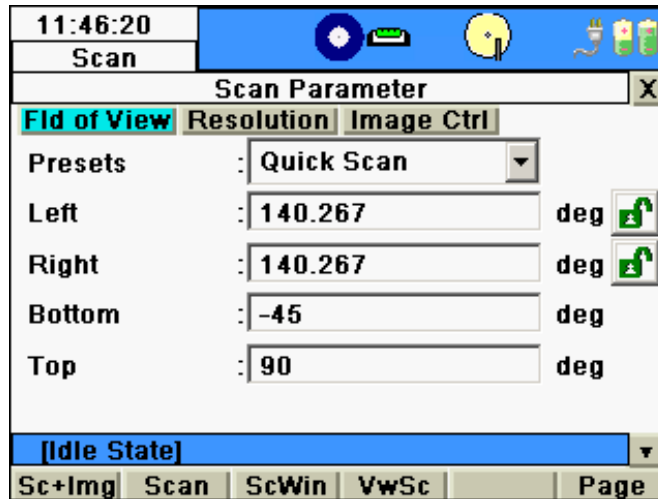


Figure 15: Target Parameter screen.

A total of four stations, one station for each side of the bridge, were scanned in a counter-clockwise fashion. Target locations at the Skew Arch Bridge were moved as new stations were set up for Station 02.

A total of four targets were used at Station 02, six targets were used at Station 03 (the front of the bridge facing the plaque) and a five targets were positioned and recorded for Station 04. Stations 01- 04 (see Appendix 1).



Figure 16: Station 02 Target Positions for Skew Arch Bridge.



Figure 17: Station 03 Targets at Skew Arch Bridge.



Figure 18: Station 04 Bridge Path view

Table 1. Scan Stations and Target Listings for Skew Arch Bridge

July 24th Thursday Set up 11:25 a.m.				
Project:	Skew Arch Bridge			
Project Name :	Skew Arch1			
Description:	Skew Arch			
Creator:	MRS			
Station ID:	00001			
Targets:	1	SA1 Top	2	SA1 Bot
	3	Hill1 Top	4	Hill1 Bot
	5	Arch		
	6	SA2 Top	7	SA2 Bot
Station ID:	00002			
Targets:	1	Left Hill1 Top	2	Path1 Top
	3	Path 2		
	4	Woods top		
Station ID:	00003			
Targets:	1	Left3 Top		
	2	Slope Top	3	Slope Bot
	4	Bridge Top		
	5	Rt Pole Top	6	Rt Pole Bot
Station ID:	00004			
Targets:	1	Stump		
	2	Top Path	3	Bot path
	4	Top Rt Side	5	Bot Rt Side

Scanning Engine House #6

On July 26, 2013, targets and stations were established for scanning Engine House #6. The interior of the Engine House was not scanned. Four stations with targets were recorded on each side of the building, and scanned in a counter-clockwise order starting at the front of the building.

A total of seven targets were placed and recorded for Station 01; four targets were used and recorded for Station 02, Station 03, and Station 04 (see Appendix II).



Figure19: Station 01 preparations at front of Engine House #6



Figure 20: West Side of Engine House # 6.



Figure 21: Back View of Engine House #6



Figure 22:View of East Side of Engine House # 6.

Table 2: Scan Stations and Target Listings for Engine House #6.

July 26th Friday Set up 10:45 a.m.				
Project:	EH6			
Project Name:	EH6			
Description:	Engine House			
Creator:	MRS			
Station ID:	00001			
Targets:	1	EH6 Lf top	2	EH6 Lf Bot
	3	EH Rail Front Lf		
	4	EH Rail Front Rt		
	5	EH Back Top		
	6	EH6 Rt top	7	EH6 Rt bot
Station ID:	00002			
Targets:	1	West Wall 1		
	2	West Wall 2		
	3	EH6 Lt top	4	EH6 Lf Bot
Station ID:	00003			
Targets:	1	Hill side 1		
	2	Front face top	3	Front face bot
	4	West Wall 1		
Station ID:	00004			
Targets:	1	EH6 Rt top	2	EH6 Rt bot
	3	Front face top		
	4	Hill side 1		

Scanning the Lemon House

On July 29,2013, the last of the series of targets and stations was established for scanning at the Lemon House. As with the other structures, four stations with targets were recorded for each side of the building, and scanned in a counter-clockwise order starting with the back of the

Lemon House. Five targets were placed and recorded at Station 01: five targets were used for Station 02; three targets were used for Station 03, and in the last area, five targets were used for Station 04. Stations 01- 04 (see Appendix 3).



Figure 23: Back View of Lemon House at Station 01



Figure 24: Side View of Lemon House for Station 02.



Figure 25: Front View of Lemon House for Station 03.



Figure 26: View of Lemon House for Station 04.

Table 3: Scan Stations and Target Listings for Lemon House.

July 29th Tuesday Set up 10:25 a.m.				
Project:	Lemon House			
Project Name:	LH			
Description:	Lemon House			
Creator:	MRS			
Station ID:	00001			
Targets:	1	Lft Top LH	2	Lft Bot LH
	3	Rail LH		
	4	rt top LH	5	rt bot LH
Station ID:	00002			
Targets:	1	Fence rail		
	2	Lft Top LH	3	Lft Bot LH
	4	Field Rd Top	5	Field Rd Bot
Station ID:	00003			
Targets:	1	Nt Pole Top	2	Nt Pole Bot
	3	Fence rail		
Station ID:	00004			
Targets:	1	rt top LH	2	rt bot LH
	3	ground est Nt Pole		
	4	Top	5	Nt Pole Bot

Processing the Data from the Scans

According to Rapidform web site “Because 3-D scanners collect immense amounts of data, specialized software is needed to process the output into something usable in other software applications. The most common applications for 3-D scans are reverse engineering, inspection,

digital archiving, and 3-D printing” (Rapidform, 2013). For this project, the Leica “Cyclone” 3-D Point Cloud Processing Software was used to process the data for the scans of the Skew Arch, Engine House #6, and the Lemon House taken at the Allegheny Portage Railroad Historic Site. The Cyclone software enables the creation of registered 3-D images using two or more-point cloud scans which can also be applied to 3-D modeling (Leica, 2013). After the data is downloaded into the Cyclone program the “Navigator” screen appears with the information’s location on the server’s folder. Expand on the folder and locate the project and continue to the registration window under configuration. After the project is registered it can be opened in model space to deleted any unwanted items.

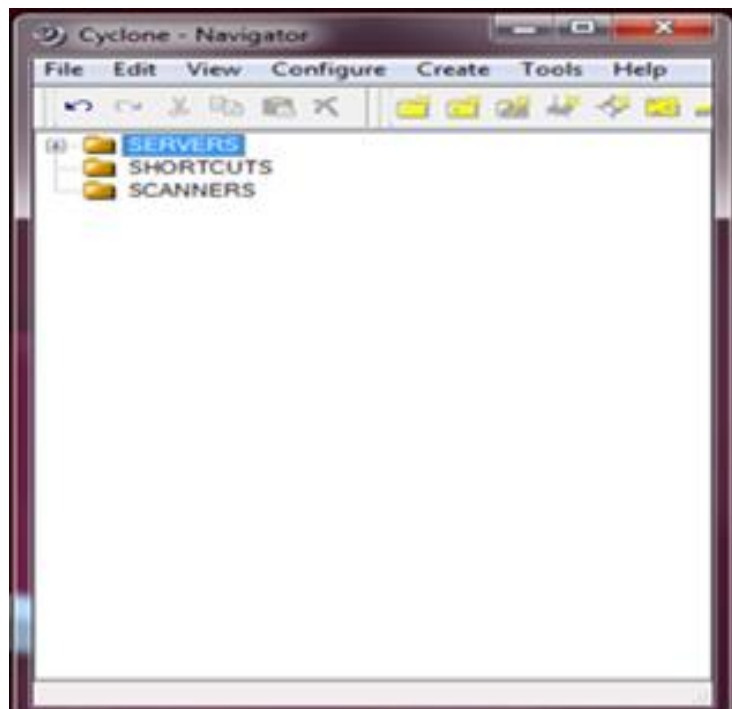


Figure 27: Opening window of Cyclone Program.

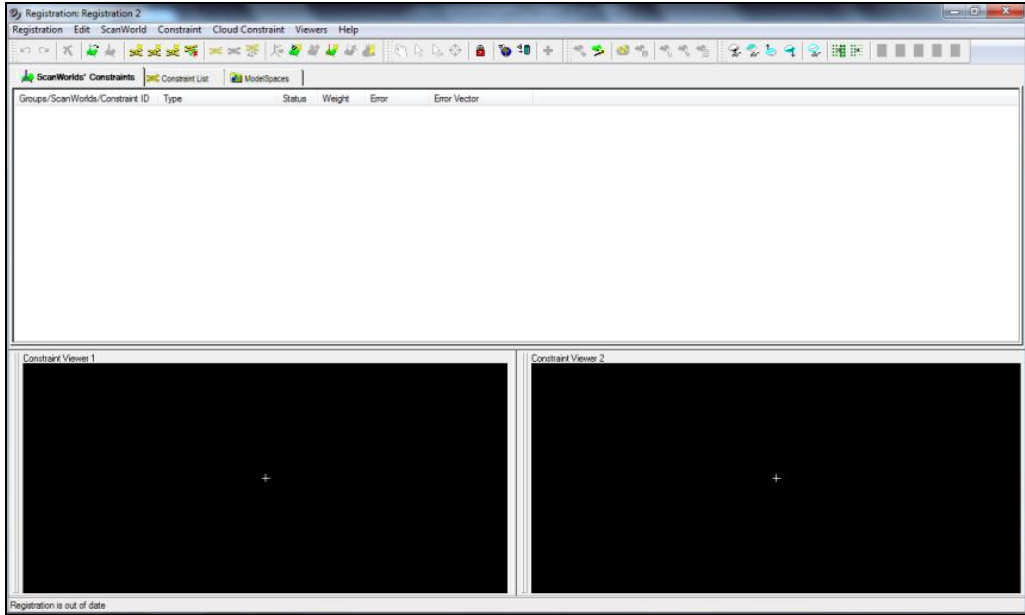


Figure 28: Registration window of Cyclone Program.

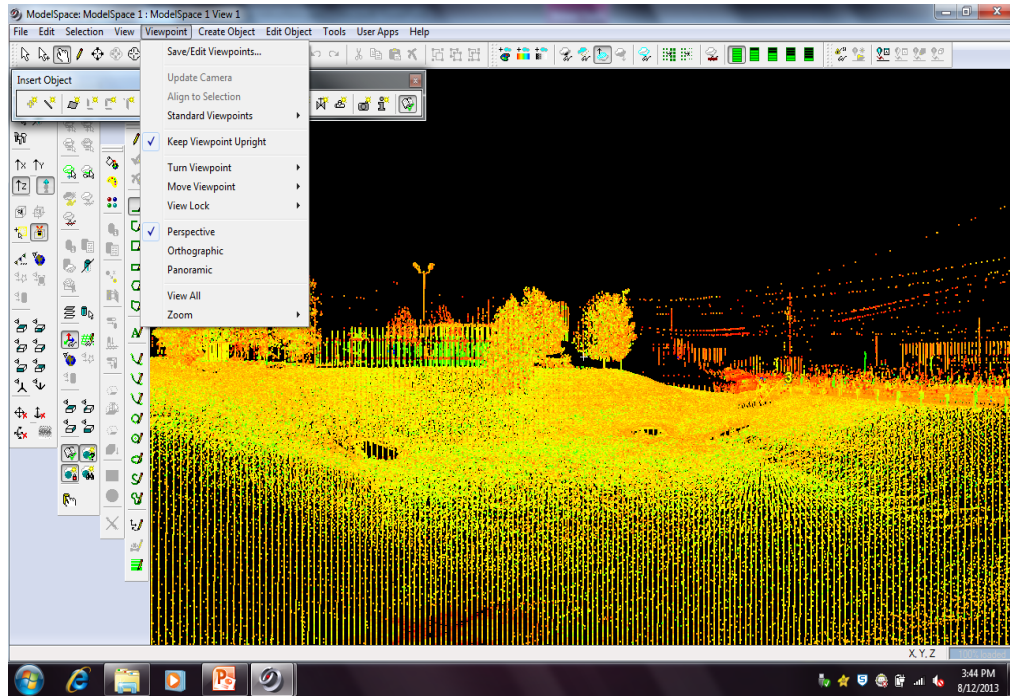


Figure 29: ModelSpace window Model View in Cyclone Program.

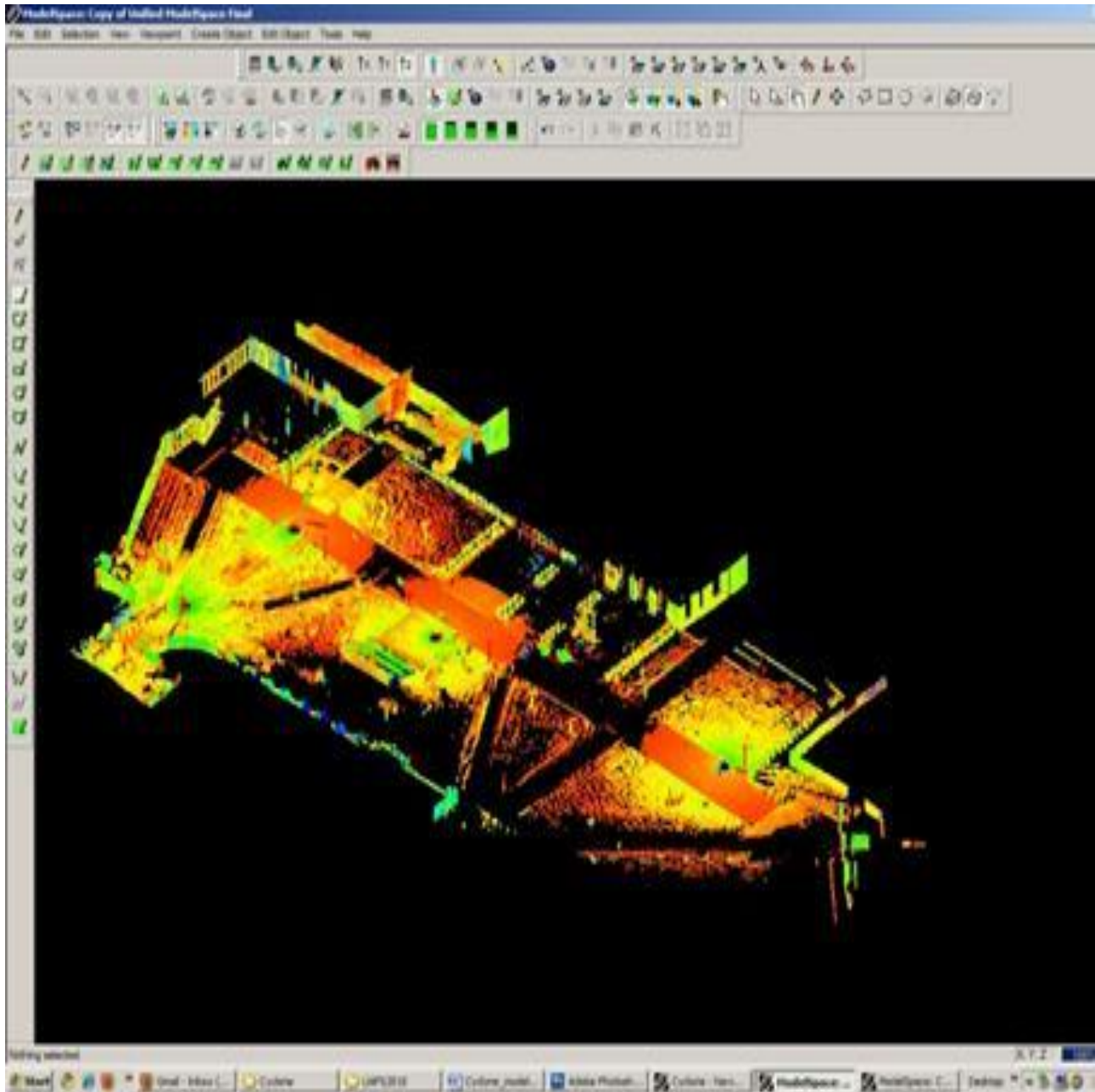


Figure 30: A building copied to a ModelSpace and “cleaned” of unneeded surfaces and vegetation leaving only the ground plane to be modeled. (Courtesy of Cyclone Help)

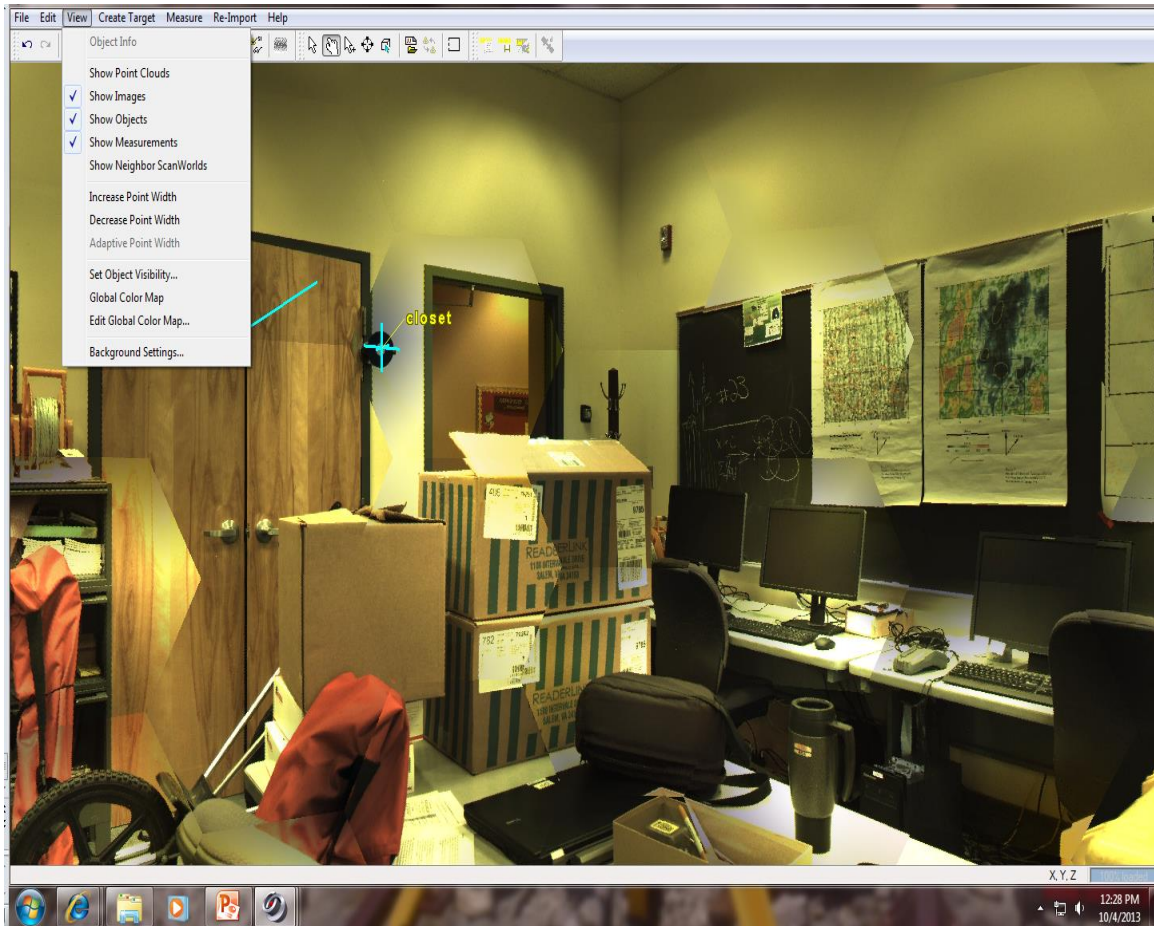


Figure 31: TruSpace window listing options from View tab.

From the Geospatial reference material (Geospatial, 2014). “Some common tasks performed in Cyclone include aligning individual scans, merging point clouds, applying color data to scan data, and creating primitive models. It is often used in conjunction with other modeling software such as Rapidform or AutoCAD” (Geospatial, 2014).

To create a 3-D model in Leica Cyclone, the instructions found on the web page (Leica Cyclone) for Leica Cyclone 7.0, state, “In Cyclone, models are based on 3-D point cloud data. CAD models involve more than only shapes as they can also convey information, such as materials, processes, dimensions, and other user-specific details” (Leica Cyclone 7.0. 2011).

“To model in Cyclone, you must use: Objects: Patches: Primitives (Create Object → Fit to Cloud or Fit Fenced): Beware: When an object is created, the object replaces the points that it

represents. It is useful to replace or reference these points if more detail or comparisons are needed (this must be done immediately after object is created as the capability is eliminated as modeling progresses)” (Payne, 2011).

To create a detailed completed model of each structure for this project, the modeled sections of the individual structure were aligned, using the images and measurements from Cyclone, with a built-in 3-D modeling program on the VIBE virtual platform. The built-in modeling program, similar to Google SketchUp, can be used in applications such as creating 3-D architectural, interior design, and engineering.

The models, created on the virtual platform, were made from linked prims. The term “prim” is a shortened version of "primitive" and refers to the 3-D polygonal shapes on a builder’s work station. “Each prim created on the work space is represented by a set of parameters, including shape/type, position, scale/size, rotation, cut, hollow, twist, shear, etc. The color, texture, bumpiness, shininess, and transparency of the prims can be adjusted (or stretched), and images (textures) can be applied to each surface (face/side) of a prim to change its appearance. The box, cylinder, and prism prim shape types can also be made flexible such as giving the appearance of a waving flag “(Primitives, 2009). Objects or 3-D models created on the virtual platform from the work space can also be exported to other programs such as Google Earth, in several 2-D and 3-D formats: such as COLLADA (. dae), or OBJ (geometry definition file). In total, 87 prims were created for the Skew Arch Bridge model, 13 prims were used for the Engine House # 6 model, and 247 prims were made for the Lemon House Model. The completed 3-D models were then individually recorded on a black background with the video screen capture program, while the model turned on the screen to show all four sides of the completed structure.

After all the models were recorded in movement, each was placed on two adjoining regions (virtual land) located on the VIBE grid. With guidance from the staff at the Allegheny Portage Railroad Historic Site, the regions referred to as Portage and Allegheny were landscaped using other objects created by prims, as well as land elements such as hills, waterways and valleys, resembling the real world locale as it may have been at the time the structures were originally built. The models then had textures applied to the face sides, which were similar to the details and color shade of the original structures, and positioned as seen in the real world.

In addition, the Lemon House model, located in the Allegheny region, was modified to incorporate additional internal elements, such as rooms, walls, ceilings and period style furniture, so virtual visitors could walk through and tour the home's interior as it may have looked in the 1800's.

In the last stage of production, images and the videos illustrating the various stages during the development of the project were combined into a single .wmv video titled "Portage Project," with screen captures of photos taken at the site and inserted next to the recreated historical structures. The models that first emerged as sections from the data processed with Cyclone software can be seen in their entirety and environment, both on the virtual platform and on-line (Facebook page at Allegheny RR historic site).

CHAPTER V

RESULTS

In order to achieve the visual effects needed for a versatile audience and virtual landscapes, several steps were required. First, all the data collected from the scans taken at the four stations from the Skew Arch Bridge, Engine House #6 and the Lemon House, were processed individually, as summarized in Chapter IV. The screen captures below show a small portion of the areas and stations produced, with some variances in the background and angles of view, with general summaries.

Figure 32 shows Station 01 at the Skew Arch Bridge in the ModelSpace window with the labeled targets, the target positions, and scan station location marked by the colored **X** (red), **Y** (green), and **Z** (black). The trees and structure colors against the black background help distinguish what can be removed from each layer without mistakenly deleting parts of the bridge during the “cleaning” stage.

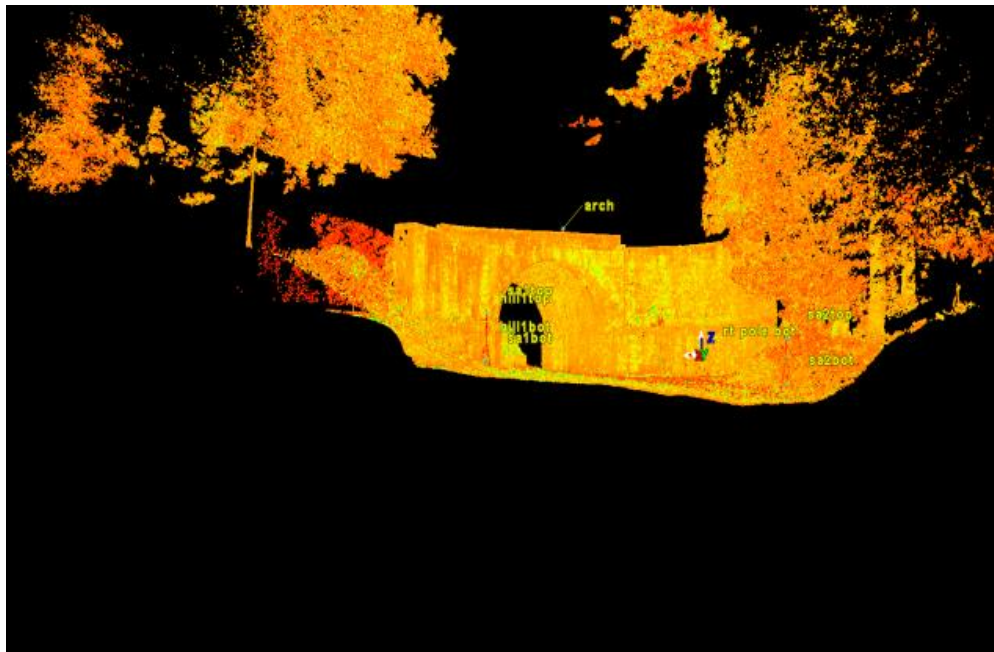


Figure 32: ModelSpace view of Station 01 at the Skew Arch Bridge

Figure 33 is Station 03 at the Skew Arch Bridge. In this ModelSpace view, all trees and land are completely absent from the structure section. By omitting these components, the entire section can be viewed from all angles without obstruction, making the labeled targets, target positions, and scan station location more visible. By adding the structure's "image," the original image captured with the scanner, the details in the stonework can be seen, as well as the keystones in the arch, and the steps located on each side of the bridge to the archway.

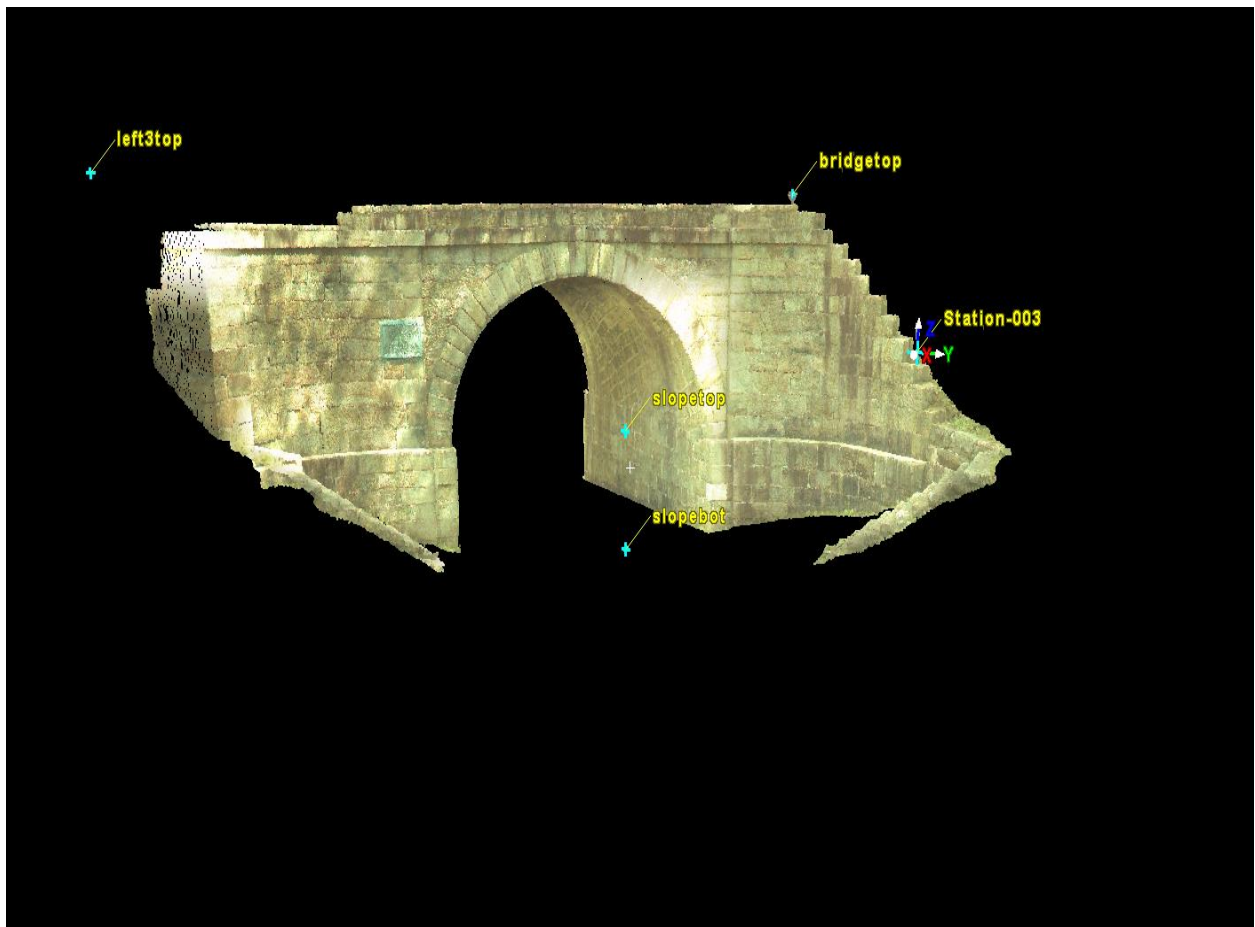


Figure 33: 3D Model of Station 03 at Skew Arch Bridge created in ModelSpace.

Figure 34 shows the screen capture from TruView of the Engine House #6. The image shows some locations of the targets from the combined stations. With the TruView viewer program, “the original scan data point clouds are “distilled” into pixelated images” (Great Lakes Geomatics, 2013), so viewers can see exactly what the scanner saw from that location and, depending on the settings, the other scanner locations. This image is part of the *Publish Site Map* files, which offer portability of all the scanned data to be viewed with the Leica TruView software (mentioned in Chapter IV). Other Leica TruView features and benefits are (Great Lakes Geomatics, 2013):

- View TruView file sets locally or via the web
- Accurate coordinate and point-to-point measurements
- Use high-resolution images and true-color point clouds
- Text and graphic markup capabilities
- Collaboration via saving and sharing of views and markups
- Incorporate hyperlinks to asset information within views

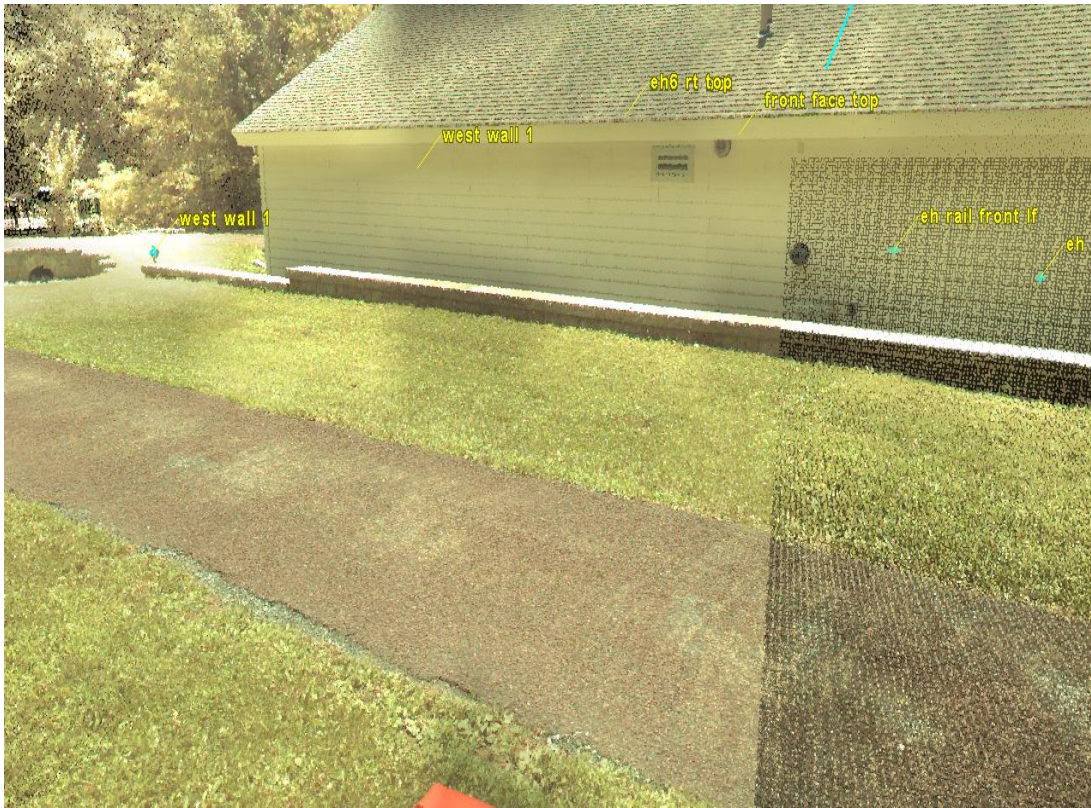


Figure 34: TruView of Station 04 at Engine House #6.

Figure 35 is a screen capture from Station 03 of the Lemon House as it was rotating. To achieve this still, all unwanted elements were first *fenced* and removed in ModelSpace. The model of the section was then recorded while rotating with Debut Video Capture Software, a video screen capture program. The video capture of the rotating Station 03 from the Lemon House, shows the structure's face as well as some elements in the interior of the structure as seen in this still. This video, as with the others that were taken for all stations and locations, was saved as a .wmv (Windows Media Video) file, which can be easily shared and viewed with others without the need to install additional software.

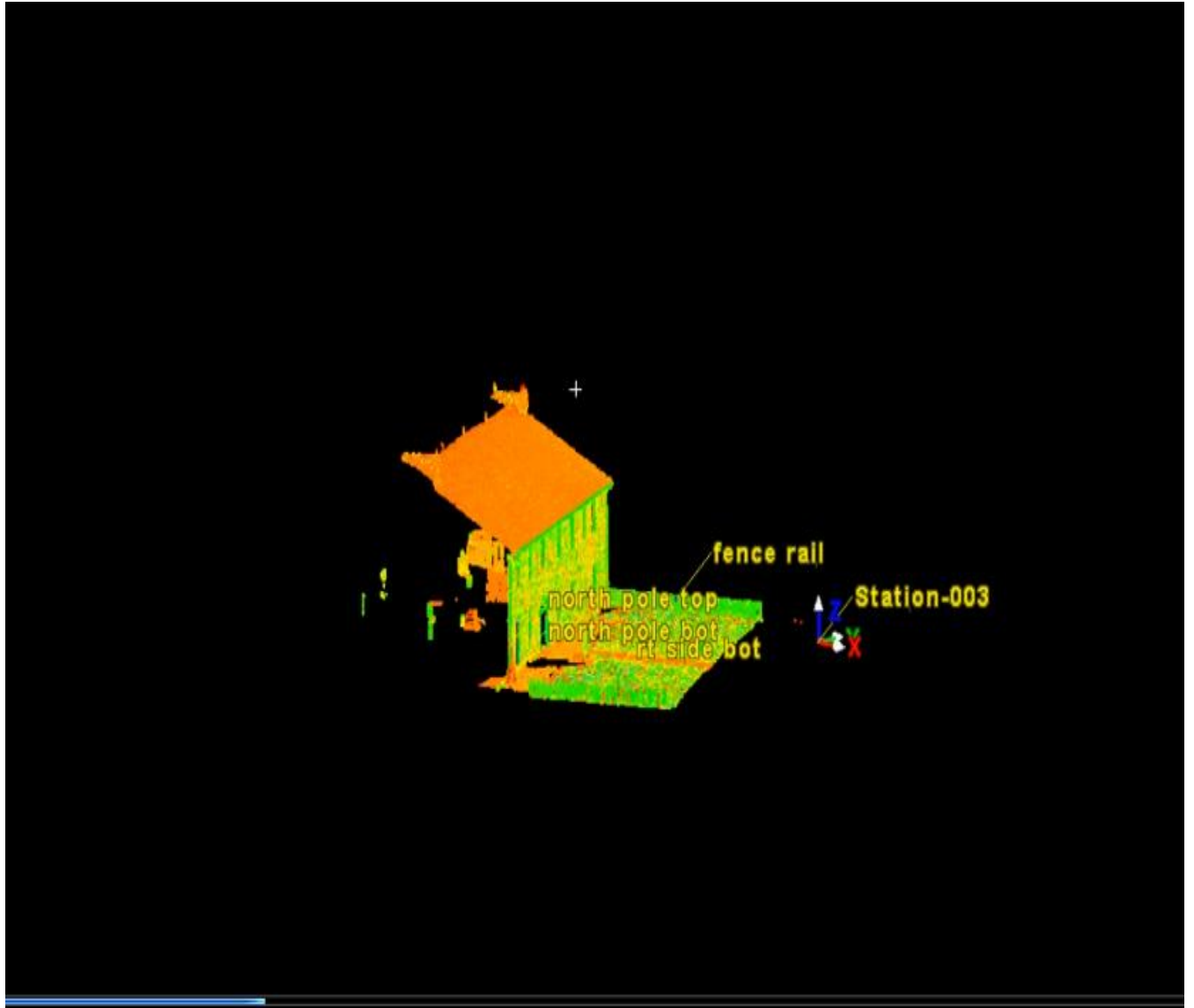


Figure 35: Screen Capture of Station 03 Lemon House video

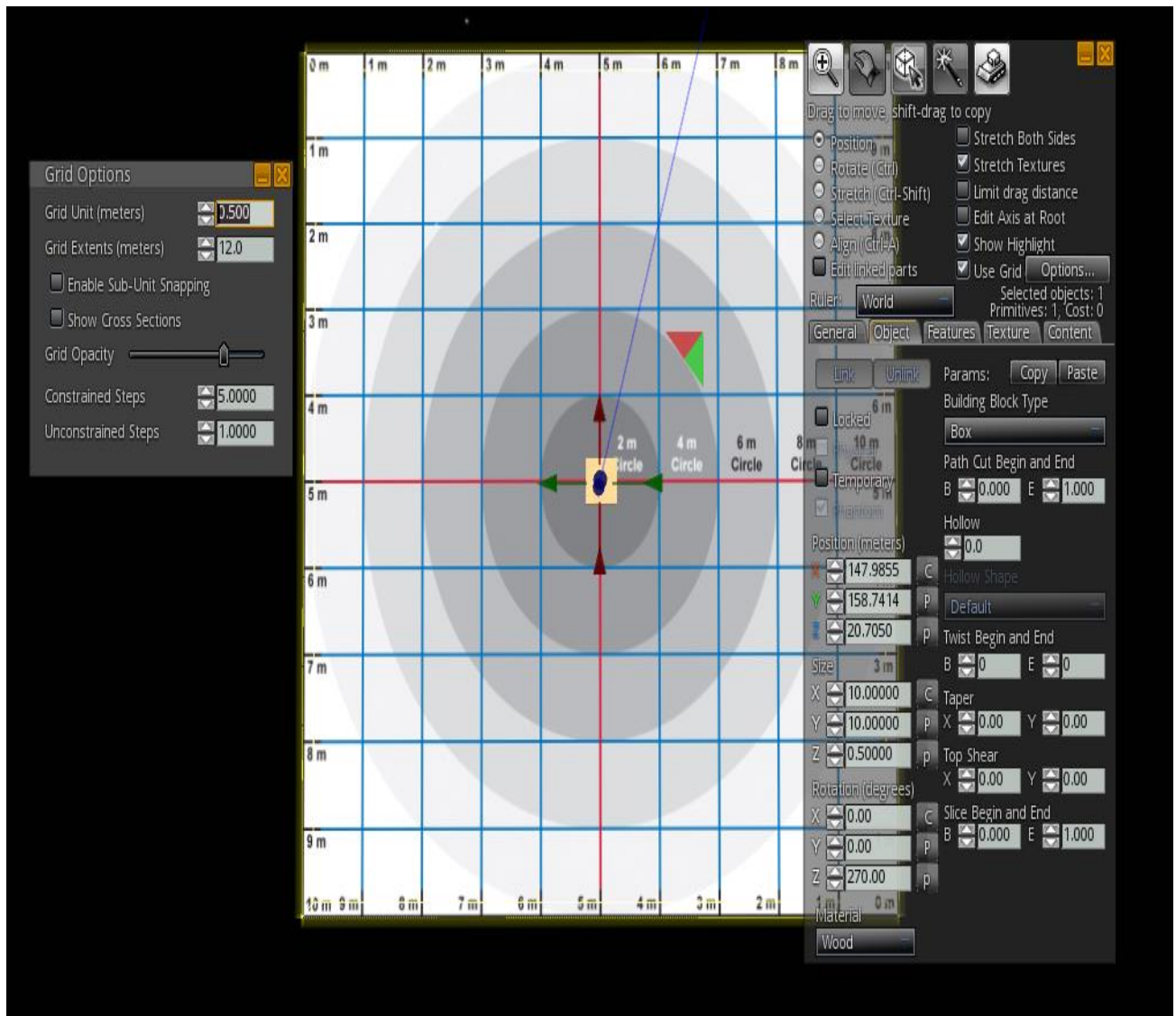


Figure 36: View of work area and tools on virtual platform.

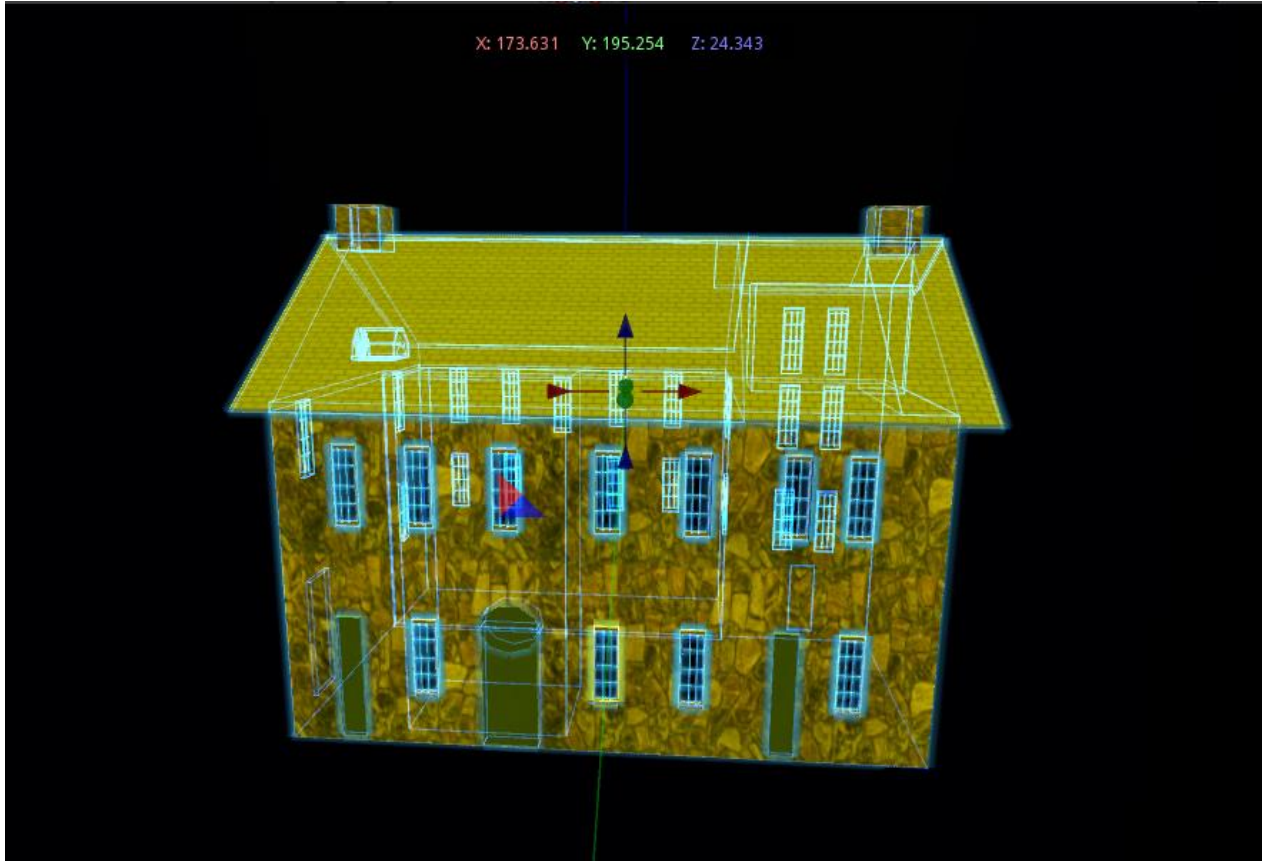


Figure 37: Completed reconstructed model of the Lemon House.

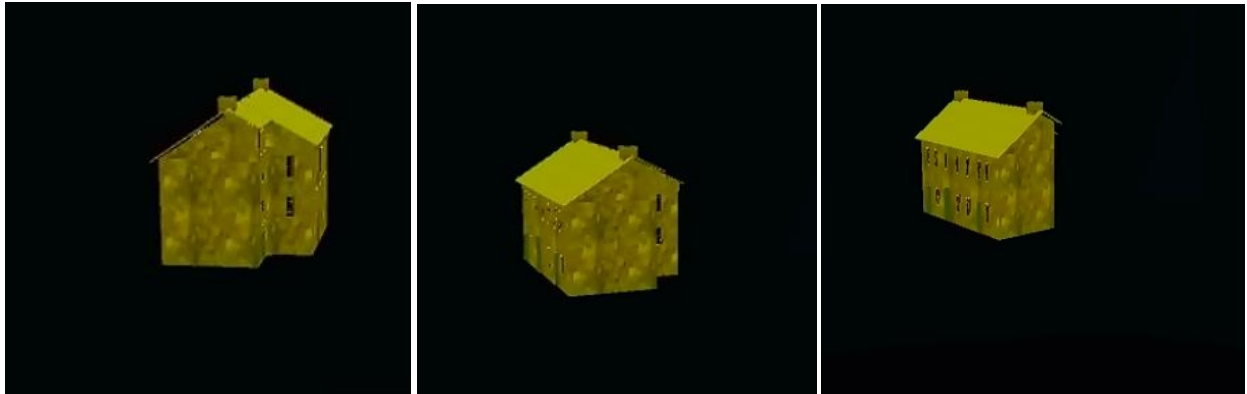


Figure 38: Different views of Lemon House 3D model.



Figure 39: Skew Arch Bridge in Virtual Setting



Figure 40: Screen capture from Portage Project video



Figure 41: Lemon House in Virtual Setting

CHAPTER VI

CONCLUSIONS

In conclusion, the Leica C10 scan station was relatively easy to set up and to maneuver through the screens, using the various icons to scan the historic structures. Dr. Scott Moore from the history department at the university was kind enough to show me the basics of setting up the scanner unit and how to take test scan. However, the Cyclone software was not originally instinctive and has a steep learning curve. Learning to use the Cyclone software to process the data from the scans was at first awkward and frustrating.

In order to complete this project a series of calls were made to the Leica tech support. With their help, I was able to access the areas in the program needed to continue through the “Training Flowchart” as outlined by the Leica representative. Having worked previously with CAD, some of the commands and features in the model space window were familiar to me, and if I was unsure of a command, the description could be found in the 610 pages of the Help Section within the program. Having overcome these problems, the resulting processed data from the scans produced by the Cyclone software were informative, and impressive to myself and others who had no former concept or understanding of 3-D scanning.

Finally, with the completed models on a virtual platform, the structures are placed in a landscape similar to how they may have been seen at an earlier time, and can be used as a teaching aid for educators, a public outreach extension of the NPS, and a means of promoting tourism to the area.

The portability and other features described for the Leica TruView software, that enable viewing the file sets from each location, will be extremely helpful to the Allegheny Portage Railroad Historic Site if they choose to use the software. The new information provided from the

scans will help the APRR further their preservation efforts, with the aid of the architectural renderings and image components. They now have a faster way of assessing their standing, built structures and documenting stability over time. The additional video showing the images of the processed project offers even more viewer flexibility to a wider audience and can be used in visitor/ site interpretation.

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Appendix A

Skew Arch Bridge Stations and Targets

Station 1: The total of seven targets were placed at Station 01 and recorded as followed;
Target 1: SA1 Top and Target 2: SA1 Bot. The Targets 1 and 2 were on a twin-target pole positioned near the far left corner of the bridge. Target 3: Hill1 Top and Target 4: Hill1 Bot, were on a twin-target pole positioned on the embankment near the front of the bridge and visible through the bridges arch. Target 5: Arch, was a singular sphere target placed on the estimated center point of the bride top above the arch. Target 6: SA2 Top and Target 7: SA2 Bot, were on a twin-target pole positioned near the far right corner of the bridge.

Station 2: The total of four targets were placed at Station 02 and recorded as followed;
Target 1: Left Hill1 Top, this target remained in the same position from Station 1, only the top target on the pole was used for the Station 2 scan. Target 2: Path1 Top, only the top target on the twin target pole was used, this target was positioned on the left corner of the path. Target 3: Path3; was a singular sphere target placed on the right corner of the path. Target 4: Woods Top, only the top target on the pole was used and positioned at the right side wood line of the path.

Station 3: The total of six targets were placed at Station 03 and recorded as followed;
Target 1; Left3 Top, only the top target on the twin target pole was used and positioned at the upper far left corner of the bridge. Target 2: Slope Top and Target 3: Slope Bot, was the twin target pole placed near the left side of the arch of the bridge. Target 4: Bridge Top was a singular sphere target placed on right top corner of the bridge. Target 5: Rt Pole Top and Target 6: Rt Pole Bot was the twin target pole placed to the far right of the bridge.

Station 4: The total of five targets were placed at Station 04 and recorded as followed;
Target 1: Stump, a singular sphere target placed on a stump located on the far left side of the bridge path. Target 2: Top Path and Target 3: Bot Path was the twin target pole placed at the far

end of the bridge path. Target 4: Top Rt Side and Target 5: Bot Rt Side was the twin target pole placed on the far right side of the bridge path.

Appendix B

Engine House #6 Stations and Targets

Station 01: The total of seven targets were placed at Station 01 and recorded as followed:

Target 1: EH6 Lf top, and Target 2: EH6 Lf Bot was the twin target pole placed on the far left corner of the building. Target 3: EH rail Front Lf, was a singular sphere target placed on the far left rail in front of the building. Target 4: EH Rail Front Rt, was a singular sphere target placed on the far right rail in front of the building, Target 5: EH Back Top was the top target of the twin target pole that was positioned at the back of the estimated center of the building, Target 6: EH6 Lt Top and Target 7: EH6 Lt Bot was a twin target pole placed on the far right corner of the building.

Station 02: Four targets were used for Station 02 and recorded as followed: Target 1:

West Wall 1, this was a singular sphere target placed on the far left corner of the building. Target 2: West Wall 2, this was a singular sphere target placed on the far right corner of the building. Target 3: EH6 Lt top and Target 4: EH6 Lt bot was the twin target pole on the far right corner of the building that was placed previously for Station 01.

Station 03: Four targets were used for Station 03 and recorded as followed: Target 1: Hill

side 1, was a singular sphere target placed on the far left corner of the back of the building. Target 2: Front face top and Target 3: Front face bot, was the twin target pole placed in the estimated center of the front of the building. Target 4: West Wall 1, was a singular sphere target that was previously placed on the far left corner of the building for Station 02.

Station 04: Four targets were used for Station 04 and recorded as followed: Target 1:

EH6 Rt top and Target 2 EH6 Rt Bot, was the twin target pole on the far right corner of the building that was placed previously for Station 01. Target 3: Front face top, was the top target on

the twin target pole placed in the estimated center of the front of the building for Station 03,
Target 4: Hill side 1, was a singular sphere target placed on the far left corner of the back of the
building that was previously placed for Station 03.

Appendix C

Lemon House Stations and Targets

Station 01: The total of five targets were placed at Station 01 and recorded as followed:

Target 1: Lft Top LH and Target 2: Lft Bot LH, was the twin target pole placed on the far left of the building, Target 3: Rail LH, was a singular sphere target placed on wood rail of the estimated center of the back of the building, Target 4: rt top LH and Target 5: rt bot LH, was the twin target pole placed on the far right of the building.

Station 02: Five targets were used for Station 02 and recorded as followed: Target1:

Fence rail, was a singular sphere target placed on wood fence on the left corner of the building.

Target 2: Lft Top LH and Target 3: Lft Bot LH, was the twin target pole that was previously placed on the far left of the building for Station 01, Target 4: Field Rd Top and Target 5: Field Rd Bot, was the twin target pole placed near the edge of the field on the far left of the building.

Station 03: Only three targets were used for Station 03 and recorded as followed: Target

1: Nt Pole Top and Target 2: Nt Pole Bot, was a twin target pole placed on the far right of the front of the building, and Target 3: Fence rail, was a singular sphere target placed previously on wood fence on the left corner of the building for Station 02.

Station 04: In the last area five targets were used for Station 04 and recorded as followed:

Target 1: rt top LH and Target 2: rt bot LH, was the twin target pole that was previously placed on the far right of the building for Station 01, Target 3: ground est, was a singular sphere target placed on the ground at the estimated center of the side of the building. Target 4: Nt Pole Top and Target 5: Nt Pole Bot, was the twin target pole previously placed on the far right of the front of the building for Station 03.

Appendix D

Flow Chart for Cyclone Software

In order to achieve the desired results for this project a Training Flowchart, created by a Lecia representative, was used that summarized how to process the scanned data with the Cyclone Software. Additional information or details of each mentioned on the flow chart, were found in the Help Manual in the Cyclone program.

Transfer Project: The Flowchart states to create and name a file Scanner Projects on the hard drive. This file will contain the project scans that shows each process is completed. The Projects database files will add: ModelSpaces, ScanWorlds, Registrations, Images and any Imported Files associated with that particular project.

Import Project: From the Cyclone Navigator screen the database is opened and a selected project can be chosen to be imported into the program. The instructions stated that it is important to use the import C10 data option specifically, to ensure all data imports correctly. The first project chosen from the database and imported into the Cyclone program was named Skew Arch Bridge. The imported information then needed to go through Registration. From the Cyclone Help Manual: “Registration is the process of integrating the ScanWorlds for a project into a single coordinate system as a registered ScanWorld. This integration is derived by using a system of constraints, which are pairs of equivalent or overlapping objects that exist in two ScanWorlds. The objects involved in these constraints are maintained in a ControlSpace, where they can be reviewed, organized, and removed. They cannot be moved or resized in the ControlSpace. The registration process computes the optimal overall alignment transformations for each component ScanWorld in the registration, such that the constraints are matched as closely as possible.”

Create Model Space. When all registration steps are completed, the ModelSpace window can be opened to create and define any details from the image shown on the screen and start the steps of creating a 3-D model. From the Cyclone Help Manual: The ModelSpace window provides visual access to a ModelSpace View, primarily used to view, manipulate, and measure scan data or point clouds. ModelSpace tools allow you to segment the point clouds into smaller subsets, which can then be used to fit specific geometric shapes. Various geometric objects can also be inserted and manipulated. More complex shapes and text annotations can be added using the 2D drawing functions. The Status Bar at the bottom of the ModelSpace window displays information about the current ModelSpace, including counts of selected objects, the layer of the object selected last, the distance between the last two picks (if available), the angle between the last two picks (if appropriate), and the progress of the loading of objects.

ModelSpace View, the Station 01 image of the Skew Arch Bridge was viewed from all angles. A fence, which are 2-dimensional rectangles or polygons that are used as a boundary to select or delete objects, located in the tool bar, was used on unwanted components such as tree's, and removed from the view of the structure. Once the image was "cleaned" of unwanted items it was selected again with a fence and opened in a new model space. In the new model space view, any additional cleaning was done by zooming into specific areas or to look at different layers within the model. When the model was completed, the Station 01 section of the bridge could be completely rotated to show all exterior and interior components of the scanned structure within that view. At this point, a model can also be saved with screen capture software and then viewed on any computer that supports video format files such as avi, an Audio Video Interleave file or wmv, a Windows Media Video file.

Create Key Plans and TruSpace. From the Cyclone Help Manual: “When using the The Key Plan command, located on ModelSpace window tool bar, the Key Plan displays the locations and orientations of scanners to a background image that provides context. The background image is typically a 2D drawing or model”. “A TruSpace is used to view the scanned scene from the scanners point of view, measure distances between two points or extract targets”. There are several options that can be chosen from the View tab on the TruSpace window, that offer different views with other components or with just one option when checked.

Publish Project. To Publish a project from the Key Plan window, go to File tab, then click on Publish Site Map. This option creates a Sitemap as HTML with links to TruView image sets Panoramic point cloud and image file sets, including photographic background imagery for viewing with Leica TruView software that can be downloaded for the Leica web site.