

## 1. Administrative Information

- Institution: The Center for Wooden Boats
- Project title: Monitoring Artifact Dimensional Stability Using Photogrammetry
- Award amount- \$24,748 Total Project Cost- \$26,050
- Project date: October 1, 2013 – September 30, 2014
- Program Director: Kyle Hunter
- Partner Organizations: Taggart Objects Conservation, Seaport Boatworks, Northwest Seaport

## 2. Project Summary

The Center for Wooden Boats led a year-long experiment to develop a new, low-cost method for using digital photogrammetry for long term monitoring of the condition of large objects and test the possibilities of this software to aid in documenting objects. The collection, storage, and care of large objects present ongoing challenges for museums of all sizes. Due to their size it is often necessary to store large objects in less than ideal collection storage conditions. Using six scenarios common to the storage of these objects that small museums or historical institutions would be likely to encounter, CWB staff, consultants, and volunteers began to collect a majority of the data to develop the process using digital photographs processed in *Agisoft Photoscan*. This method was used to create 3D models for the purpose of comparing changes in shape of an object over time, creating lines drawings of small craft, and documenting scaled complex objects not easily measured by hand.

Furthermore, this method of building 3D models was compared to other technology available on the market (like stationary laser scanning (LiDAR) to test the quality of its results.

## 3. Process

In each scenario, a virtual 3D model was made of an actual boat, and in one case a Totem Pole. A 3D model is a representation of an object using a collection of points plotted on a grid with an x, y, and z coordinate system. Though there are many ways to create 3D models of an object, this research project primarily focused on building 3D models using an inexpensive software program called *Agisoft Photoscan*.

For each object, multiple, overlapping digital photos were taken to capture the object in its entirety. The software works by aligning common points in multiple photos and plotting those points on an x, y, and z axis in 3D space. These models were then used in three other software programs depending on the desired outcome: *Rhino3D*, *AutoCAD*, and *Cloud Compare*.

Most of the photography of the project was completed in December of 2013, when all of the project partners convened for a workshop over five days to collect over 250 GB of photographic, laser scanned, and surveyed data to be later processed and compared. Over the next nine months, the data was processed into 3D models, where they were used as the basis for virtually comparing the actual objects, virtual dividing them into

sections and measuring them to make detailed lines plans and construction drawings (blueprints), or using the virtual objects to compare the quality of the different methods of capturing the data of the actual objects.

The majority of the resources of this project supported the labor to take photographs, process models using software, and creating a guide available for other institutions that may be interested in employing this method to achieve similar outcomes.

#### 4. Project Results

The intended result of this project was to develop a cost effective, simple method to monitor the condition of irregularly shaped large objects over time and additionally document these objects for posterity. **An initial startup cost of \$3100 provides the equipment** (includes computer, camera, software, and accessories) capable of building 3D models as seen here, digitally compare them, and create lines plans.

##### **Exhibition in the water: Twilight**

Twilight is a NW built 36' fishing trawler built in Seattle, WA in 1933 by Harold Hansen. A once common double ender of the era, she was acquired in 2000 by Northwest Seaport, a partner organization for this project.

In December of 2013, while floating in the water, the team comprised of project partners took a complete set of digital photographs from various vantage points around the vessel. Twilight was moved repeatedly throughout the photo shoot, and photographs were taken from other floating boats and from the pier.



The resulting model generated in *Photoscan* was remarkable. The two mainstream ways in use today, stationary LiDAR laser scanning and Total Station survey, are not capable of generating a model of an object in motion.

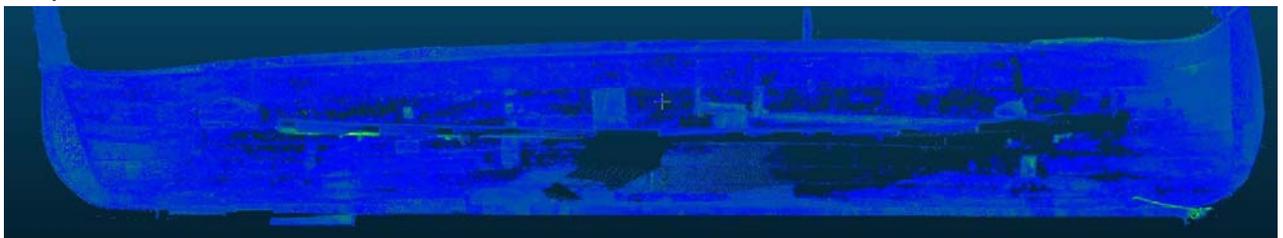
Later, in July of 2014, Twilight was hauled out and trucked up to Pt. Townsend, WA for storage out of the water. Another set of photos were taken after she was blocked up. The model that we created of the latter shoot was “merged” in *Agisoft Photoscan* with the model from the former, resulting in a model of the boat in its entirety. NW Seaport has a base model of Twilight to monitor her dimensional stability by comparing it to later models built from future photo shoots. See below screenshot.



### Exhibition on land (“on-the-hard”): Nordic Spirit

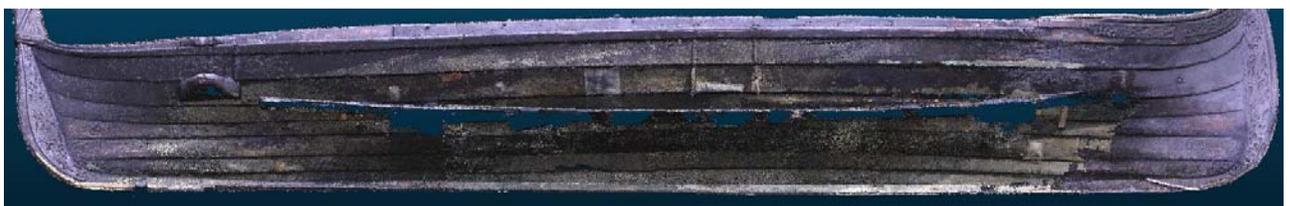
*Nordic Spirit* is a large, Viking-style ship built in Northern Norway approximately 200 years ago. It is currently owned by the Nordic Heritage Museum in Seattle, WA, and is on permanent display under a covered outdoor section in front of the museum. Because of the age of the vessel, it was prudent to make a good base model to monitor its stability.

*Nordic Spirit* was scanned using a stationary LiDAR laser scanner, an instrument capable of capturing immeasurable detail but with a total price tag of \$125k. In this case, the vessel was supported by several obstructions that left significant “holes” of information in the model. Due to the nature of the scanner and limitations in mobility, it is not possible for the scanner to read obscured areas.



3D model built using Stationary Laser Scanning (LiDAR)

A model of the boat was also built in *Agisoft Photoscan*, using a digital camera. While no technique is able to penetrate obstructed sections of the object, a camera is small enough to work around in the majority of tight spaces. A more complete model was created using this method. This model is a good base to compare future models to in order to monitor the stability. It also serves as an illustration of the versatility of the *Photoscan* method.



3D model built in *Photoscan*



actual boat. The length of the boat was within 1/8<sup>th</sup> of an inch and the width within 1/16<sup>th</sup> of an inch.

**Storage, un-cradled, minimal environmental controls: 1929 *Reinell* Runabout**

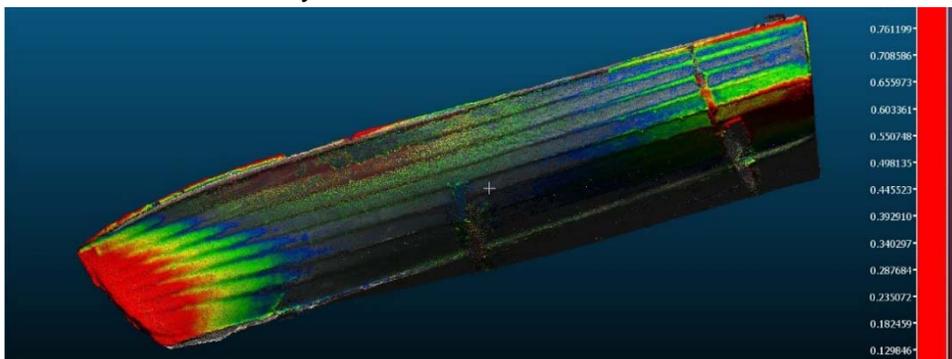
To accelerate the process of an object changing shape over time in order to come to a conclusion on whether these software programs were capable of recognizing the change in the shape of a hull, CWB used a derelict recreational fishing boat built in 1929 to physically manipulate that very change.

A 3D model of the *Reinell* was built using the same method explained with the *Mukilteo* boat above. To simulate the shape change that might occur over time, we set up two lead weights cantilevered out over the gunnels of the boat, in opposing directions and at opposite ends of the boat, thus giving the hull a definite and perceptible twist. Then, mimicking elapsed time of a lengthy period, as might occur with an improperly supported boat, we created a second 3D model. We repeated the photographic process to minimize any possible errors arising from a change in camera settings or photographer, and built models using the same parameters in *Photoscan*.



Exporting the models from *Agisoft Photoscan* as a standard .ply file and uploading them together into *Cloud Compare*, we were able to align the models to the points most common to each model.

*Cloud Compare* provides the user with a classification of points that appear in a color range that represent the deviation between the two 3D models, thereby highlighting the differences between the physical hulls. The red coloring illustrates the most extreme differences between the two models, while the areas without coloring represent sections of the boat unaffected by movement.



In order to qualify the actual distance of movement into relative units of measurement, the model needs to be scaled in *Rhino3D* prior to uploading into *Cloud Compare*. More overall research is needed to determine the level of accuracy using this software, as only one simulation of a shape change of an object was able to be tested. However, based on other studies in this project, the accuracy level is estimated to be roughly 1/8inch error over 20 feet.

If highly accurate measurements are needed before further research is conducted using the baselines of other models in this project, the total station survey is a proven method to measure that movement. The *Vhasa* Museum (<http://www.vasamuseet.se/en/>) has done an excellent job of geodetic measuring using total station survey that produces results with an error less than 1mm.

### **Used in CWB sailing program, in and out of water: (*Blanchard Junior Knockabout*, small-craft keelboat)**

The Center for Wooden Boats cares for a fleet of eight *Blanchard Junior Knockabouts* (*BJK*). Seven of these boats are used roughly 1000 hours per year, while the eighth is archived and stored out of the water. All of these boats were built on Lake Union in Seattle, WA during 1933 and 1947. The story related by Norm Blanchard Jr., the son of the builder, is that building the first few *BJK*'s too many planks were broken during construction due a strong curve at the bow of the boat. In order to prevent this from happening further, the design was elongated slightly to lessen the curve. Of the eight that CWB owns, one is the shorter version at the 19' length compared to the longer at the 19'8" length. While the length is easily distinguishable to the eye, the complex curvature in the shape of the bow is more abstract in nature and therefore more difficult to comprehend and ultimately compare. Comparing the 3D models in *Cloud Compare* gave insight into viewing the differences on a different level. There are features in this program that allow the user to create cross-sections, thereby giving the user a view of differences of the surfaces. In addition, CWB has baseline information on how these boats looked in 2013, and can be compared to later models to continue monitoring for dimensional stability.

### **Non-boat structural feature: Honor Pole**

As part of this project is the focus of using the software for the documentation of objects, we found *Agisoft Photoscan* to be a highly capable tool to aid in this process. Like any cultural object or artifact made of organic material and on display outdoors, they are subject to degradation by rain, UV light, and other environmental factors that put the object's integrity at risk. It is very difficult to measure such an abstract object as this by hand; having a scaled, 3D model can provide a variety of information that other methods like photography and sketching cannot.

In addition to the construction of a model using *Photoscan*, this object was a good candidate for a direct comparison to the laser scanning method to test its viability. *Cloud*

*Compare*, the same program used in the simulation to monitor dimensional stability, was used to compare the two methods of 3D model making.



This above screen shot captures a comparison (middle) between a *Photoscan* point cloud (left) and a LiDAR point cloud (right). The pole depicted in the center is the comparison of clouds matched up using *Cloud Compare* software. The yellow, orange, and red coloring that you see represents minor discrepancies between the two models. The units shown are generic, as this model has not been scaled to the actual object.

### What's next?

- In Oregon, Clatsop Community College and Portland Community College are working with the Columbia River Maritime Museum to document NW small craft in Oregon using this technology.
- Columbia River Maritime Museum has submitted a funding request for the training of this technology local to the Northwest coast of Oregon, and the proposal has included some of the project partners that participated in this project documents boats native to the Pacific Northwest.
- The National Park Service HABS/HAER team has adopted this method based on results from this project.
- CWB will continue the process of photography for documenting vessels in its collection using the methods developed in this project.

### Recommendations

For institutions that are charged with caring for large objects under less than ideal storage conditions, the collection of and proper storage of data (photographs, measurements) is the single, most important thing that can be started to preserve the object in a scalable format. By using a good quality digital camera and spending the time to gather a proper set of digital photographs, these pictures can be processed at any point in the future. An institution initially needs only to spend the resources to learn the photographic method and techniques compatible with *Agisoft Photoscan* in order to begin collecting data that will provide baselines for comparing large objects in the future, or be applied to the other uses outlined here.

Additionally, the method described here need not be limited to the institutions described above. It can also be used as a tool to have available in addition to those techniques proven and already in use. Its portability and lightweight allow for simple

transportation and the possibility to capture a significant object without planning or in an area difficult to navigate.

Regarding object monitoring: based on the data in this project alone, *Cloud Compare* is an inexpensive process that will tell *if* the object is changing rather than by how much. Until the baseline models in this study are compared to future models of those same objects, the great value of this process is to determine whether to take precautions to stabilize the object or turn to the geodetic measuring process using the total station to provide a more precise accuracy.

Regarding documentation: based on the data in this project, this method is a powerful tool that has many benefits in comparison to documentation with other technological methods or even by hand. However, this caveat must be considered when planning out a documentation project: everything after the photographic stage that documents the object *as-is* is an interpretation. Though the 3D models that are created are highly accurate, in the process of turning these photographs into models, and then models into drawings, many compromises, idealizations and judgments are made. The quality of these products may be subtle or substantial depending on the skill of the interpreter.

To thoroughly explore the possibilities and limitations of this method, please refer to the document titled *Building 3d Models with Digital Photographs* using the link below.

## **Resources**

CWB has produced a detailed reference guide for interested institutions looking to incorporate these methods and ideas into their preservation programs. A simple “take-away” brochure has also been produced as a quick guide to showcase the possibilities of this method. These products are available at <http://cwb.org/exhibits-type/preservation-and-documentation/>.