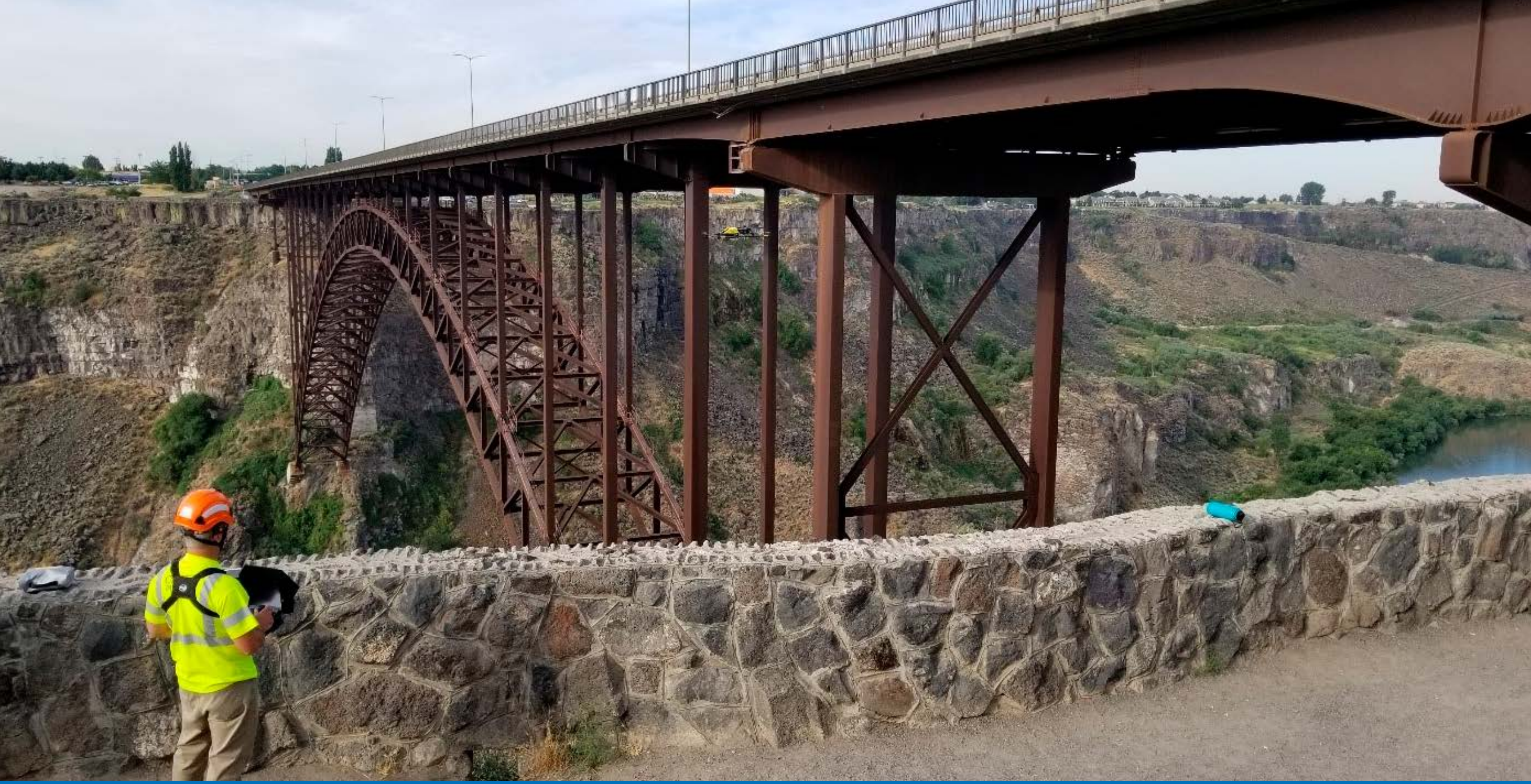


Perrine Bridge
Inspection Reality Model

Twin Falls, Idaho

IDAHO TRANSPORTATION DEPARTMENT

COLLINS ENGINEERS INC.

Overview

INTRODUCTION

The Perrine Bridge is a 1,500 ft long steel truss arch span that carries four lanes of traffic and two sidewalks over the Snake River Canyon in Twin Falls, Idaho. Construction on the bridge was completed in 1976, and the bridge is a popular tourist attraction. The bridge is distinctive in that it is the only bridge in the United States where base jumping is legal year-round without a permit. The Idaho Transportation Department (ITD) owns and maintains the bridge. The bridge is considered fracture critical because it contains steel tension members whose failure would likely cause a collapse of the bridge. As part of ITD's responsibilities, and to meet federal guidelines, the bridge is inspected every 24 months and all fracture critical members are inspected by qualified bridge inspectors at arm's length. Arm's length access to bridge elements is accomplished using rope access techniques where inspectors use ropes and climbing equipment to position themselves for inspection.

PROJECT GOAL

As part of an effort by ITD to improve the quality of the inspection and to evaluate new inspection technologies, the rope access bridge inspection was supplemented by an unmanned aircraft system (UAS) in 2019. The goal of the UAS was to take high resolution images of the entire bridge that, along with ground control information, could be processed into a 3D model of the bridge. This imaging and modeling technology is commonly referred to as 'reality modeling.' While not a replacement for the hands-on inspection, the reality model provides additional documentation that is useful for communicating inspection results, verifying bridge construction and details, and assisting in asset management. The reality model also provides ITD with a historical record of the bridge condition that can be used to evaluate changes in the condition over time.

The Perrine Bridge

Equipment

Propeller Aeropoints GCPs

Intel Falcon 8+ UAS

ITD worked with Collins Engineers to perform both the rope access and the UAS inspections.

The team used an Intel Falcon 8+ UAS, which was designed for commercial inspection and mapping purposes. The Falcon 8+ can be controlled interactively with a controller or autonomously with a pre-programmed flight. The flight controller displays the UAS's flight information, which includes a real-time map that displays the UAS's location, live image views, and flight data. The UAS is approximately 30 inches x 32 inches x 6 inches and weighs just over 6 lbs. It includes 8 propellers and 2 independent batteries for redundancy, and combined with its lightweight design, the UAS poses very little hazard to the traveling public. Flights were planned for the UAS to not fly directly over traffic for safety reasons and to comply with FAA Part 107 Regulations.

The Intel Falcon 8+ UAS imaging payload, which was the primary data acquisition tool for this effort, consists of a gimbal-mounted Sony A7R DSLR Camera which captures high resolution 36 mega-pixel (MP) still images. With pre-programmed or interactive flights, the UAS takes still images at regular intervals which are processed to produce high-resolution maps and models. The absolute horizontal/vertical accuracy of the UAS varies from 3 ft to 16 ft without ground control points and is up to 1 cm with ground control points.

In order to achieve high relative accuracy (local) and absolute accuracy (global), the team used automatic ground control points (GCPs) for this inspection. The GCPs used were Propeller Aeropoints which have a built-in GPS, solar panel, battery and WiFi. While the fieldwork is being performed, each unit collects GPS data that is

Public Outreach

automatically uploaded to a server where it is adjusted via a correction network to attain up to 1 cm accuracy. A report is generated for each GCP which gives the location and the accuracy that can be expected for each point.

The ITD Maintenance, Project and Inspection teams worked closely with regional Public Information Specialists (PIS) to ensure that citizens were aware of the project and any issues that might impact their commute.

ITD owns and maintains the Perrine Bridge which is located in south-central Idaho. The Perrine Bridge is a beautiful structure that serves the surrounding communities with access to and from Twin Falls County via US-93. While the bridge's primary function is transportation, it is also known worldwide in the extreme sporting community for base jumping.

The Perrine Bridge is one of only three crossings within 25 miles that moves motorists across the Snake River. It is by far the most used crossing in the area and has an average daily traffic count of 30,000 vehicles. The nature of this bridge (both in regard to high traffic and extreme sports) requires ITD to conduct outreach in instances where conflicts may occur.

In the summer of 2019, multiple inspections of the Perrine Bridge took place. The ITD bridge crew coordinated inspections with the district in an effort to minimize impacts to the traveling public. When possible, work was conducted during non-peak hours and lane closures were minimized. In instances where traffic control was required to be implemented on the structure, the PIS sent out advance traffic advisories to both the local media and the City of Twin Falls.

Base jumpers next to the Perrine Bridge

Public Outreach

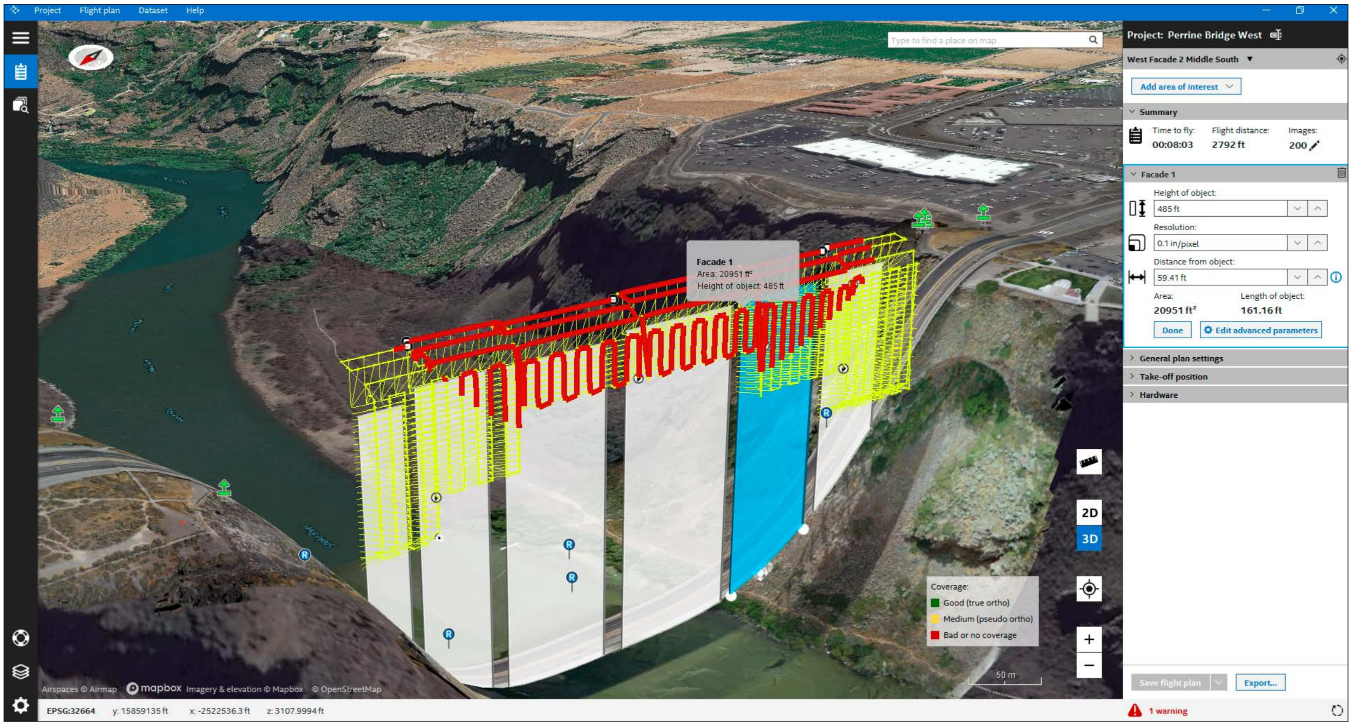
Advance Notice Flyer

While most inspections did not affect the base jumping community, communication between the PIS and the ITD bridge crew revealed the base jumpers would be affected on days when the unmanned aerial system (UAS) team was onsite. Armed with this information, the PIS developed and implemented a community outreach plan that consisted of the following:

- Presented information regarding the upcoming inspection and associated restrictions at a countywide Public Information Officers Meeting and at a Southern Idaho Tourism Meeting.
- Emailed city officials, tourism groups, known regional base jumpers, and the local base jumping school with information on the inspection and associated restrictions. Encouraged these groups to share this information with their mailing list, and also provided them with a digital flyer to post on their associated social media pages.
- Worked with the local ITD sign crew to post physical copies of informative fliers on-site at the bridge. Also posted fliers at the nearby tourism center and at local motels known to be frequented by traveling base jumpers.
- Arranged to have ITD personnel on-site to communicate between base jumpers and inspection crews regarding safe times to jump to avoid the UAS inspection activities.
- Disseminated a press release to local media.
- Coordinated an on-site interview with the UAS inspection team and local media during an inspection day.

Advance notice of the inspection and restrictions was key in the successful planning and execution of the community outreach. It allowed ample time for the creation of materials and distribution of information. Equally important was the cooperation between all parties involved who worked together to keep each other informed of scheduling, and also help spread information to all interested parties.

Execution



Flight Plan

FLIGHT PLANNING

The flight missions were preprogrammed using Intel Mission Control Software. The 3D missions were saved onto a USB stick and uploaded via the controller to the UAS prior to each flight. Flight plans were created for each bridge elevation as well as for the top of the deck. Each plan was formulated so an entire flight could be accomplished using one set of batteries. A resolution of 0.1 inches/pixel was chosen to maximize image detail and limit the total number of images to an amount that could be processed on a high-end computer in a reasonable amount of time. The flights along the bridge elevations were divided into segments which followed the arch of the bridge. The flights were programmed with a -15 degree pitch so as to not include the sky in images (sky in images can introduce noise into the processed model). An 80% vertical and 65% horizontal overlap was used to improve the model.

INSPECTION FIELDWORK

The bridge inspection fieldwork was scheduled for and completed between July 29 and August 2. Both the rope access and UAS inspection fieldwork were performed concurrently.

The first step in the UAS inspection fieldwork was to deploy the Aeropoint GCPs used to calibrate the model to near survey grade accuracy throughout the bridge site. The Snake River Canyon is accessible by trail, and the inspection team deployed the GCPs by hiking in from the west. The GCPs were placed near the bottom of the canyon and also along the south canyon wall. Having GCPs well

Execution

Placing Ground Control on Canyon Wall

distributed throughout the project both vertically and horizontally greatly improved the accuracy of the model. Since the canyon was difficult to access, the team remained in the canyon with the GCPs until enough data was collected, and then packed up the GCPs and hiked back out. Semi-permanent survey targets were left behind in the location of the GCPs so that the GCPs did not need to be redeployed for each inspection day. The semi-permanent targets were then collected at the end of the inspection.

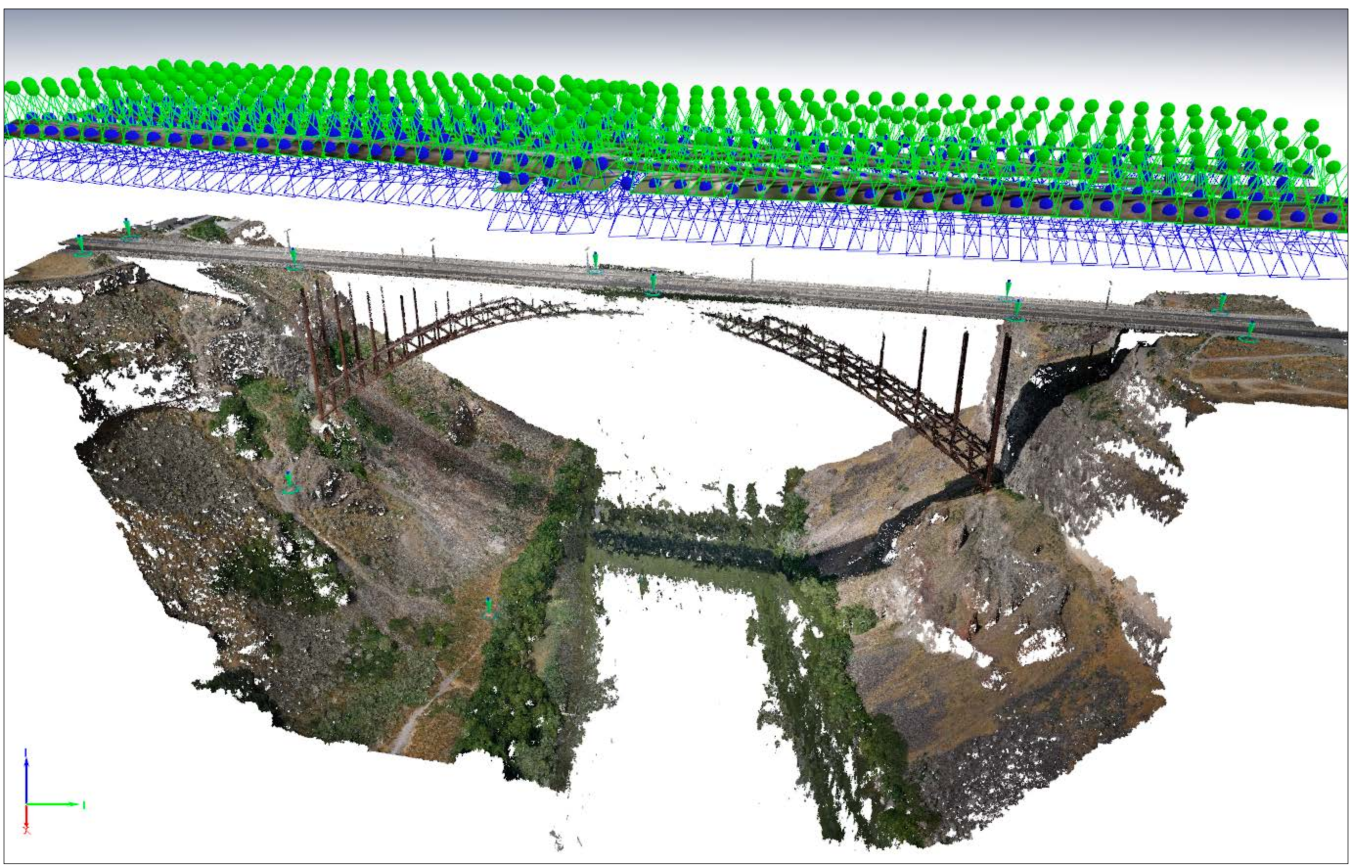
Five GCPs were also distributed along each side of the bridge deck. Small safety cones were placed near the GCPs so they were readily visible to pedestrians; not only to avoid a tripping hazard but to ensure the targets were not disturbed. Prior to placing the targets on the first day, the location was stenciled on the bridge with marking paint so each target could be placed in the exact same location on subsequent inspection days.

Intel Mission Control Software relies on satellite imagery to guide the programming of flights. Satellite imagery alone is commonly not accurate enough for inspection flight planning since inspections require flying very close to structures and other fixed objects. This was particularly true for this inspection where the imagery would be draped over steep canyon walls that create map distortions. In order to successfully perform the UAS inspection, the first day of the UAS inspection consisted of collecting data to create an orthomosaic map of the bridge. The day one flights were flown at a lower resolution since the goal was simply to define the exact location of the bridge for future flight planning. The GCPs were also distributed on day one, both on the bridge deck and in the canyon below. The orthomosaic map was then imported into the IMC flight planning software, and the previously preprogrammed flights were adjusted to match the exact horizontal and vertical extents of the bridge. The post-processed overall bridge map can be viewed here: bridge map.

It should be noted that the creation of the overall orthomosaic will not be necessary in the future since the location of the bridge will not change.

The remaining UAS fieldwork days consisted of flying the preprogrammed missions to collect the higher resolution bridge data. The timing of the flights was targeted during overcast or overcast or cloudy conditions of the day to improve the results. Collecting imagery during overcast conditions diffuses direct sunlight and minimizes the occurrence of overexposure. The UAS moves in a lawn mower style pattern collecting images with significant overlap. The flights were conducted generally from the four corners of the bridge. The landing and take-off area was delineated with an orange landing pad, and team members interacted with the public and pilot to ensure safe take-offs and landings. The pilot and team members were in constant

Overall Model of Perrine Bridge Showing GCP and Image Locations



Execution

communication through the use of radio headsets. Since there was a significant amount of base jumping from the bridge during the inspection, Amy Bower from ITD was on-site to coordinate between the jumpers and the UAS team. The flights were either paused so jumping could proceed or jumpers were asked to wait (up to ten minutes) so the flights could be safely completed. Likely due to the advanced notice and communication between ITD and the base jumping community, the base jumpers on-site during the inspection were very cooperative with no recordable incidents occurring.

In addition, manual missions were flown of the underside of the truss and deck by manually flying the UAS horizontally and looking up with the camera and triggering images at approximately two-second intervals.

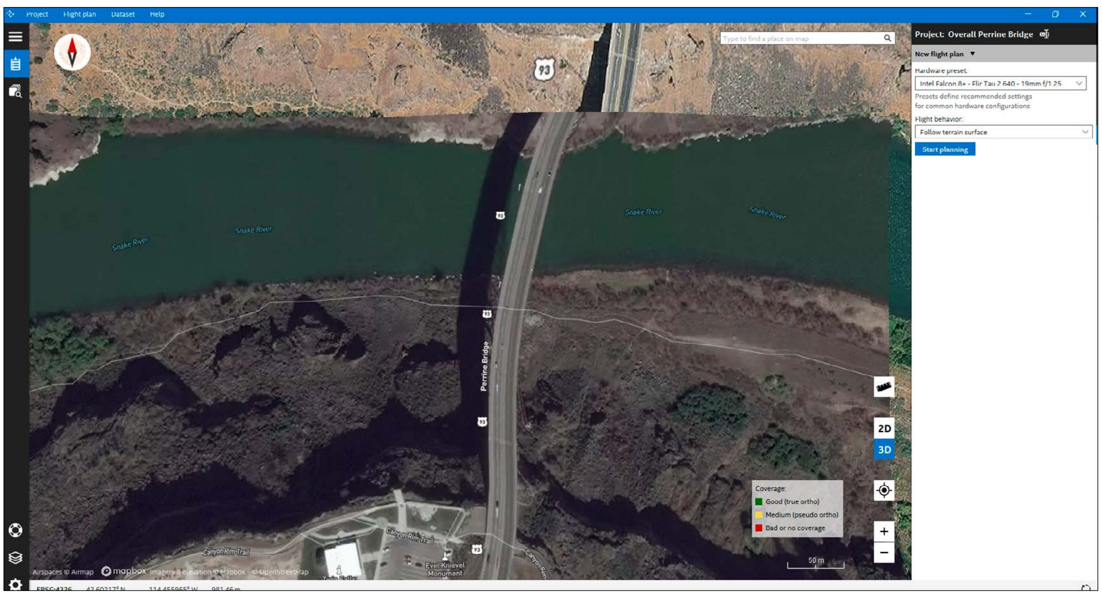
UAS Inspecting Bridge

DATA PROCESSING

The high-resolution images were post-processed using Pix4D Software to create the project deliverables. The GCPs were incorporated into the model to ensure both relative and absolute accuracy. The deliverables included an orthomosaic map of the area, a point cloud model, and a triangular mesh model of the site. The processing was performed off-site on a high-end computer, and also using Pix4D's cloud processing service. This project proved challenging to process because of the large number of high-resolution images and the topography of the canyon.

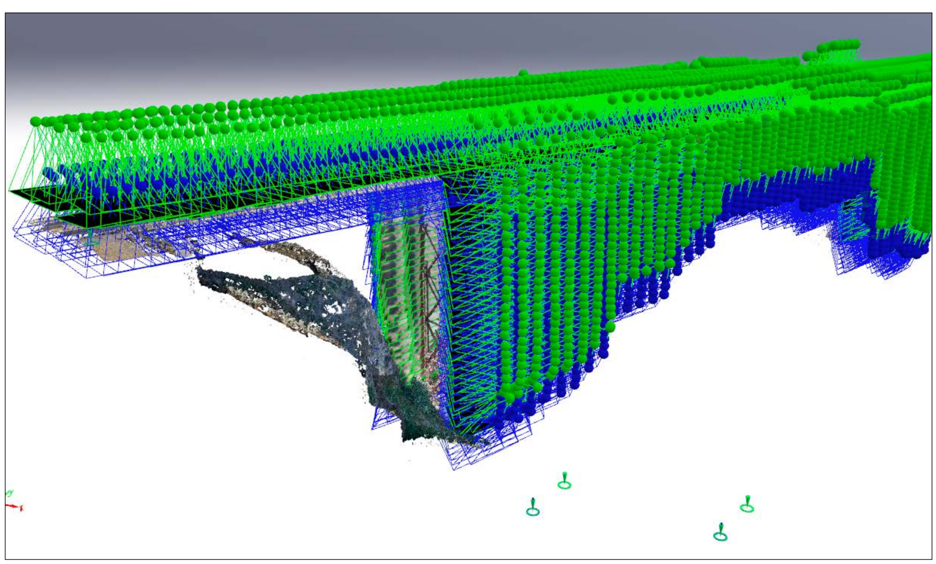
Execution

Intel Mission Control Software with Orthomosaic Background



Intel Mission Control Software with Satellite Imagery Background

Image Locations Shown in Pix4D Software



Results

The UAS inspection proved to be an efficient, safe, and cost-effective way to collect and document detailed information. The resulting maps and models of the bridge were useful to ITD in several ways, including:

- Need to list all the ways this is useful…model for current inspection, comparing future inspections, cost savings for repairs (contractors can update the model to see if their equipment can access a specific location, if their equipment fits, etc…..you kind of do that below but it would be better in a table format with photos following…..also don't forget the contractor/construction value as that may be the biggest benefit of all…..

The greatest benefit of using a high-resolution camera is that more detail can be seen in individual images. This detail is useful in both finding defects and/or deficiencies but also in documenting the bridge details at the time of inspection.

High Resolution Image Detail

High Resolution Image Detail Close-Up

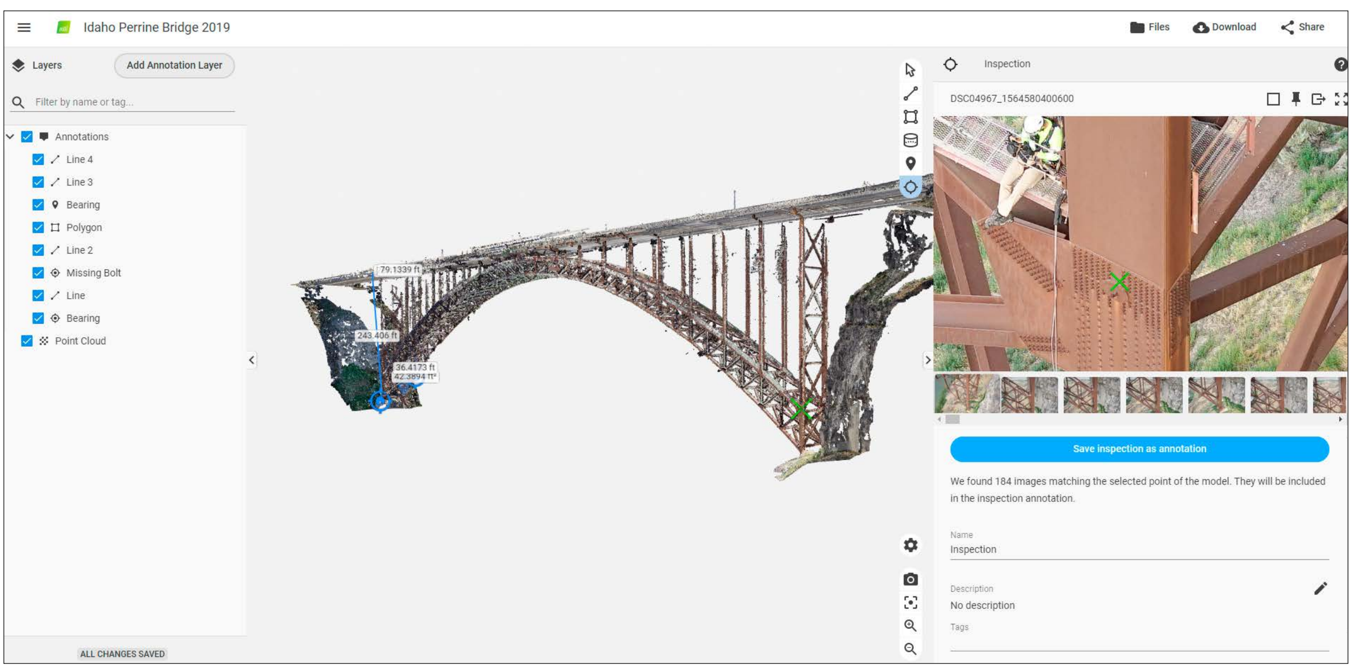
Results

The 3D model and point cloud can be used as a bridge management tool where bridge elements can be quantified, measured and documented. In addition, geospatially located bridge inspection notes can be incorporated into the model, negating the need to describe where specific defects are located.

3D Point Cloud of Perrine Bridge

Pix4D includes a cloud version which is useful for sharing the 2D map and 3D model of the bridge without having to transfer large amounts of data and without the need for the end user to have Pix4D software. The cloud version also has a virtual inspector tool that serves as a three-dimensional photo log of the inspection. Once the model is created, the photos are linked to the model. If a particular area of the bridge needs to be reviewed, the user can simply click on that point in the model and the photos will be displayed of that particular element. The cloud version also includes annotation tools to communicate results in an efficient and effective manner.

Virtual Inspector Tool



Lessons Learned

The Perrine Bridge UAS inspection is one of the largest undertakings of its kind to date. Given the challenging location, the effort created some valuable lessons learned that can be applied to future UAS inspections of this bridge or other similar bridges.

- The public involvement was critical to the success of the project. Notifying the public of the work resulted in positive interactions with the public and, more specifically, the base jumpers.
- The project required significant computer processing power, and an additional high-end computer was purchased during this phase to facilitate the completion of the modeling. Having this extra processing power at the beginning of the project would have reduced the total time to prepare the deliverables.
- Ideally the data should be collected during overcast conditions. Overcast conditions reduce the amount of shadows that makes it easier for the software to process without manual intervention and light diffusion.
- Flying a commercial quality drone purpose-built for inspection improves not only safety, but significantly improves the results in the form of improved image quality.
- Critical to the data collection effort is the use of flight planning software capable of complex 3D flights. Intel Mission Control Software accomplished this, and the ability to customize the flights made a significant difference in the ability to collect all of the data.
- Our team flew one line of images from each side of the bridge to collect the underside of the deck areas. In future inspections, we would fly at least two lines from each side at different locations and camera angles to improve the image overlap, which would have made the modeling of the underside of deck tie in better with the rest of the model.

PROJECT STATISTICS

High Resolution Images:
3,611

Time in Field:
4 days

Traffic Closures Required:
0

3D Model Points:
166,466,312

Total File Size:
166 gigabytes

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