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BUILDING DOCUMENTATION

Building Better Within Existing Conditions

WHY ITS TIME TO LEARN HOW TO USE POINT CLOUDS

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Introduction to Series

Thank you for taking the time to look deeper into the use of laser scanning on your project. We have developed this White Paper in three parts to offer our guidance as you consider how laser scanning could benefit your project.

Part One is a case study on how to validate the accuracy of a BIM by comparing it with point clouds. Once you have decided whether laser scanning can benefit your project, **Part Two** guides you through how to find and evaluate a Building Documentation Professional (BDP). Once you have found qualified professionals, **Part Three** discusses current best practices BDPs are using today that can be deployed on your project.

Part 1:

Just don't ask for a scan. Know that there are lots of challenges using scan data.

Part 2:

Contract a Building Documentation Professional for the right things.

Part 3:

What you might want to do with scan data.

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Abstract

Precise digital 3D representations of existing spaces created through the process of laser scanning are known as point clouds and can be referenced within common 3D modeling and coordination software used by building design and construction professionals. However, typical workflows used when working with geometry in modeling software are different than those used when utilizing point clouds. In the context of an actual project, this paper describes common workflows for using point cloud data. Furthermore, we present important decisions to consider before point cloud acquisition and use, and what realistic expectations to set for their use.

Key Words

Point Cloud, Laser Scan, BIM, Model Validation, Building Documentation Professional, BDP

Part 1: Limitations of a Common Approach to Validate Model Accuracy with Point Cloud Data

Introduction

Using laser scan imagery (point cloud data) to validate Building Information Models (BIMs) is commonplace in today's Architecture, Engineering, and Construction (AEC) industry. The benefits of using laser scanning to document existing conditions are numerous. However, the process to validate the accuracy of complex out-of-plumb/out-of-plane real-world conditions against a model representation, that is typically orthogonal in nature, is fraught with challenges. This Case Study will use a real-world project to illustrate a common approach to validating model accuracy with point cloud data, illustrate its limitations and look at the potential for improving the process through new means, methods, and technologies.

Background

For a university building retrofit, the architect documented the existing-to-remain space using 2D record drawings provided by the university. To support a complete and accurate construction phase BIM coordination effort, the existing conditions model needed to be validated for accuracy.

Current Conditions

Comparing point clouds to 3D solid models

Problem / Solution 1

The accuracy of 3D models intended to represent existing spaces can be validated by visually comparing them with 3D point clouds. This is done by identifying deviations; areas where 3D model geometry exists but point cloud data does not, or vice versa. To validate the accuracy of the 3D modeled existing-to-remain systems, 2D section views are placed at locations of interest, or spaced regularly over a 2D floor plan using a 3D modeling tool. Differences between the point cloud and the 3D model are found and annotated manually in the section views.

For example, the mechanical design in this project was developed based on openings in a concrete masonry shear wall dimensioned in the building's 2D as-built documentation and modeled accordingly. A laser scan was completed above the ceiling where openings in the shear wall were expected. The

actual openings were captured in the point cloud and dimensioned to verify precise location as shown in Figure 1.

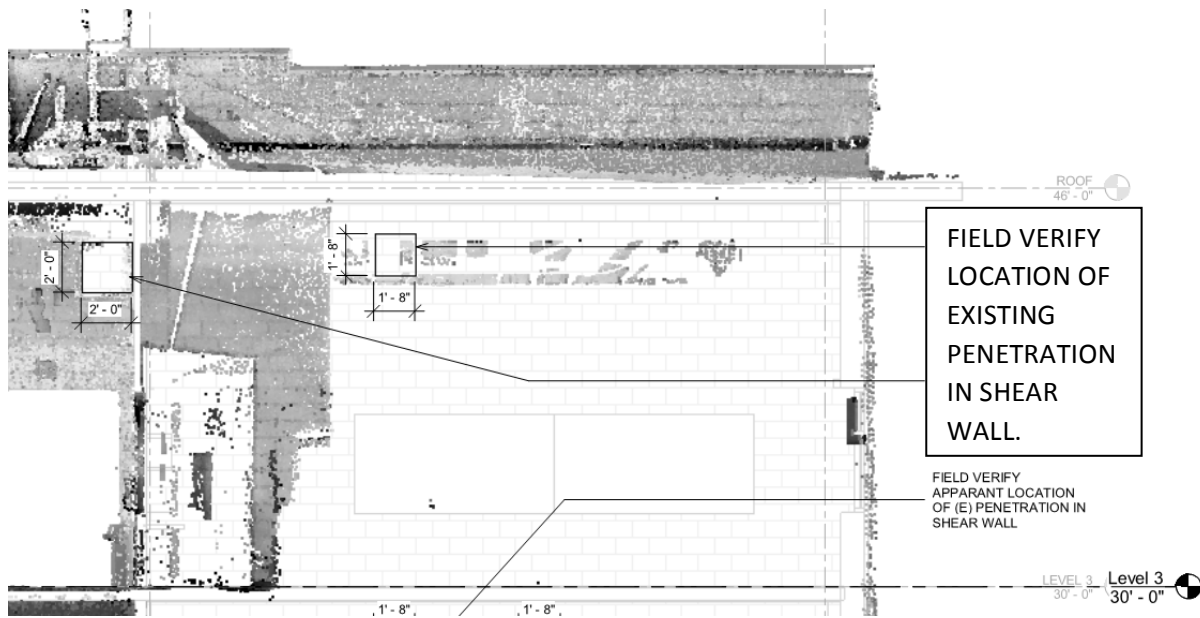


Figure 1— Elevation view of concrete shear wall showing wall penetration openings. Drawing courtesy of Koning Eizenberg Architecture, 3D Point Cloud produced by Architectural Resource Consultants, overlay and analysis produced by BN Builders Inc..

Similarly, the point cloud was overlaid with reflected ceiling plans to locate the routing of overhead systems as shown in Figure 2. The height of the reflected ceiling plan view-cutting plane can be adjusted to isolate different horizontal layers of routing.

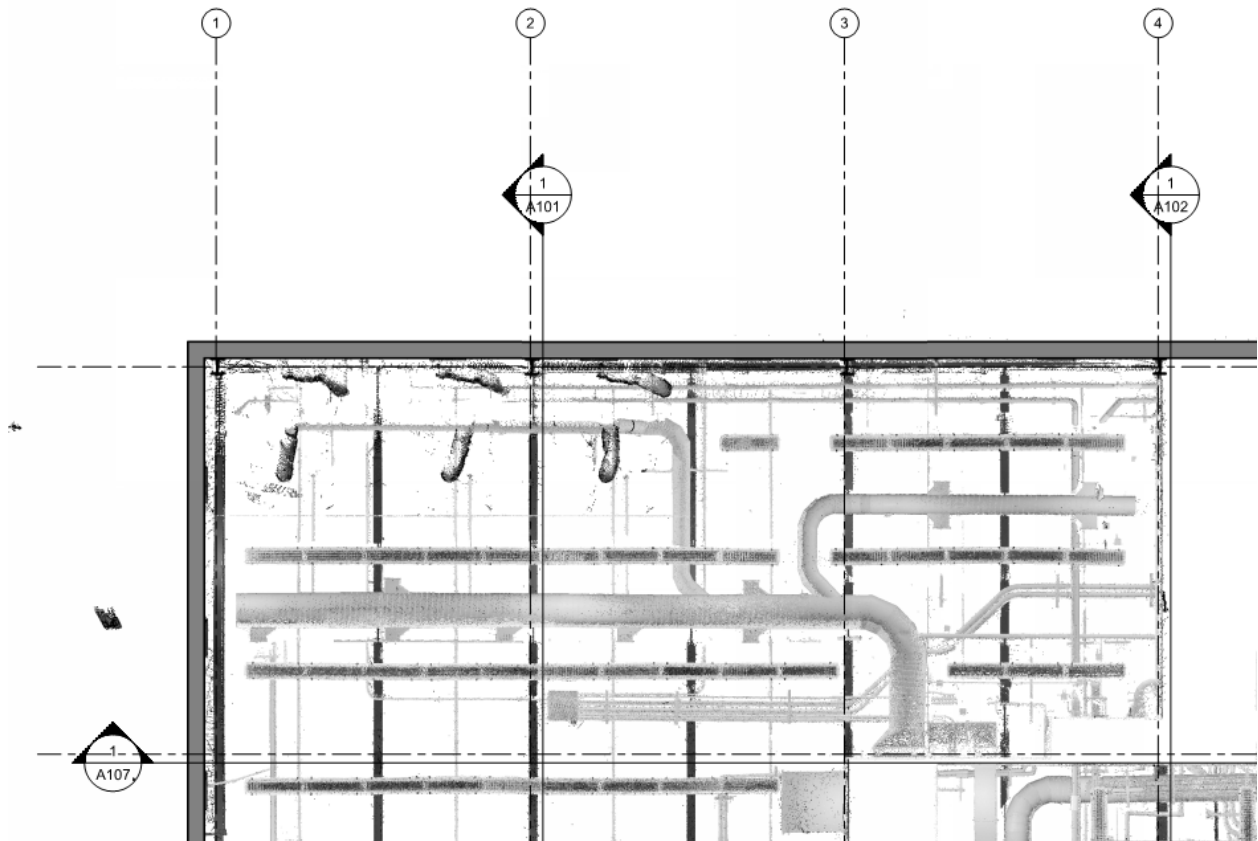


Figure 2— Reflected ceiling plan view showing overhead systems. Drawing courtesy of Koning Eizenberg Architecture, 3D Point Cloud produced by Architectural Resource Consultants, overlay and analysis produced by BN Builders Inc.

Problem / Solution 2

Using point clouds to discover unanticipated issues demands a broader approach than the one described above. Comparing the point clouds to a 3D model through regularly spaced sections will reveal missing or misplaced building systems in the 3D model such as the deviations in the shade structure identified in Figure 3. The point cloud in Figure 3 indicates the shade structure was built slightly below the designed height of the structure.

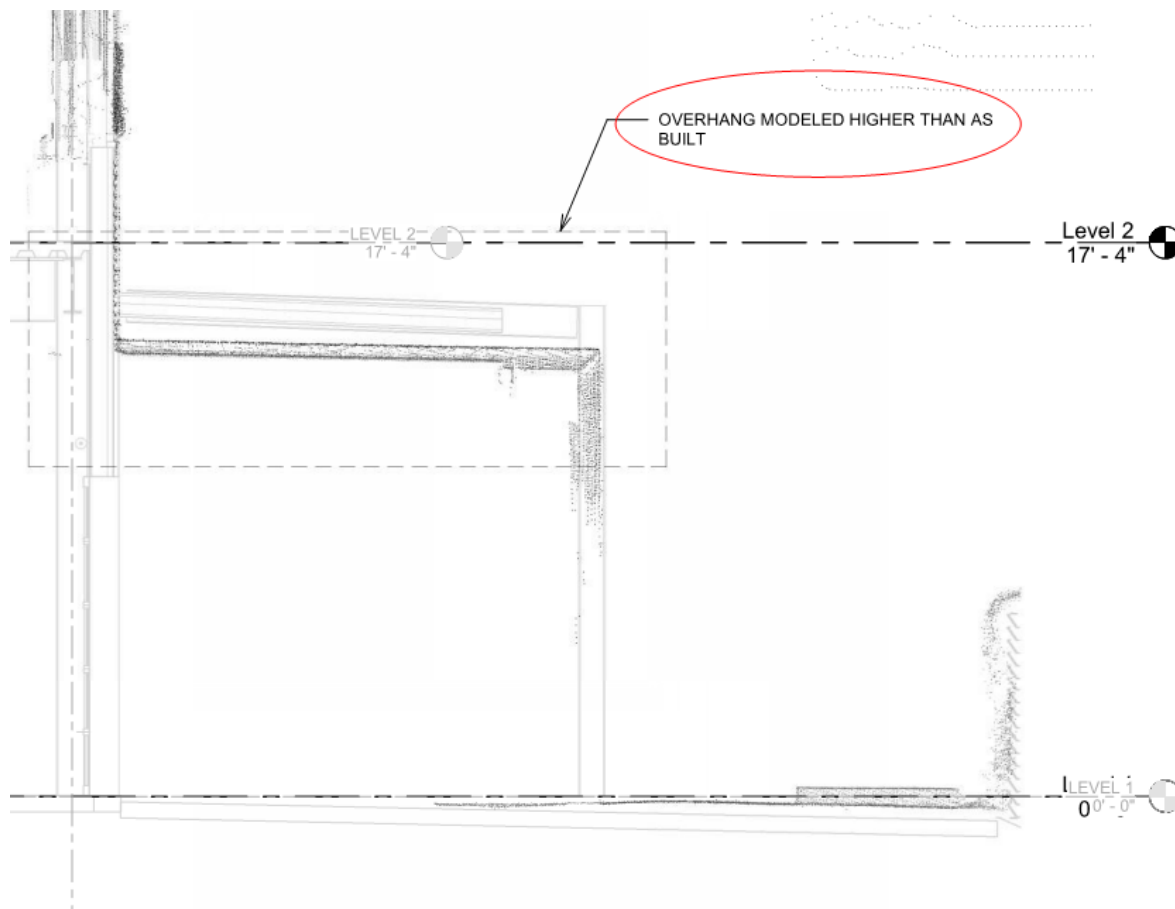


Figure 3— Section view through overhang showing conflict between the record drawing model and the point cloud. Drawing courtesy of Koning Eizenberg Architecture, 3D Point Cloud produced by Architectural Resource Consultants, overlay and analysis produced by BN Builders Inc.

Table 1: Problems & Solutions

	Problems	Solutions
1	Validate specific parts of the as-built 3D model	Set up a view in a known location to identify differences between the point cloud & 3D model.
2	Discover differences between the 3D model and what is built.	Set up and review regularly spaced 2D sections through a model that has a corresponding point cloud overlaid.
3	Discover constructability issues between the 3D model of the proposed design and what is built.	a) Clash point cloud against 3D model of proposed systems.
		b) Produce 3D model based on point cloud and clash it against a 3D model of proposed systems.

Use of the point cloud is not limited to the BIM authoring tool and orthogonal plan and section views. Perspective views based on user-defined vantage points can be set up using point cloud viewers hosted online with dimensioning capabilities as shown in Figure 4.

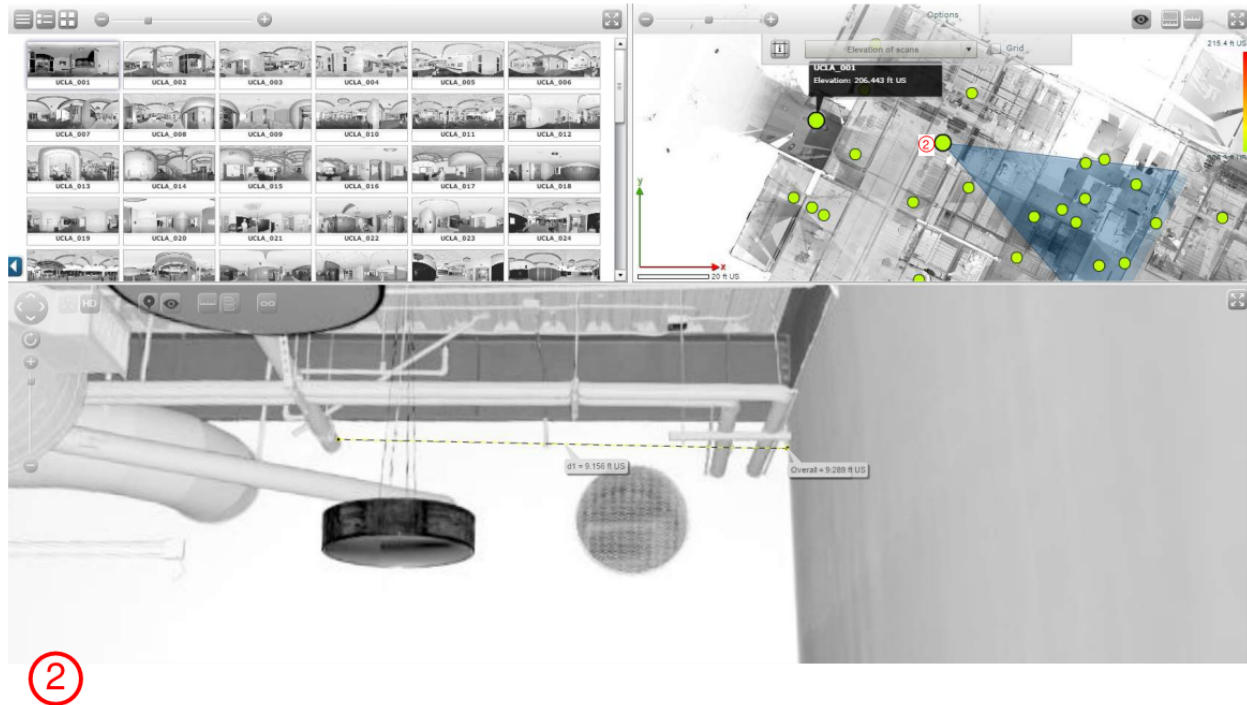


Figure 2— Web viewers give non-technical users the ability to view and dimension scan data

Why would existing-to-remain systems be documented before demolition? Mobilization for BIM Construction Coordination can take a couple weeks to get organized. While it's important to have the most accurate representation of existing-to-remain systems before you start, sometimes it's not available if demolition isn't complete. Should you start coordination without a complete and accurate representation of the existing building systems?

Given ample resources, scanning early and often might be ideal. Laser scanning on this project was performed before demolition, and only one time. During construction, many main pipes located and modeled were discovered to not be modeled accurately for coordination. As a result, the construction team had to relocate the pipes on site to accommodate main duct runs as coordinated. This was a costly option that could have been avoided had fire protection main pipes been modeled accurately for BIM coordination.

However, even when the point clouds documented fire protection mains, opportunities to resolve clashes against them with new ducts during BIM coordination were missed. Figure 5 below highlights where a point cloud clashes with a modeled duct. These clashes were discovered in the field during construction, resulting in delayed schedules, field rework and time spent from project engineers to be solved.

The process for detecting clashes between solid geometry and point clouds is different than that for clashing solid geometry only. Is clash detection with existing systems best performed after modeling the existing systems first? Part three of this series outlines steps to clash solid geometry and point clouds using Navisworks.

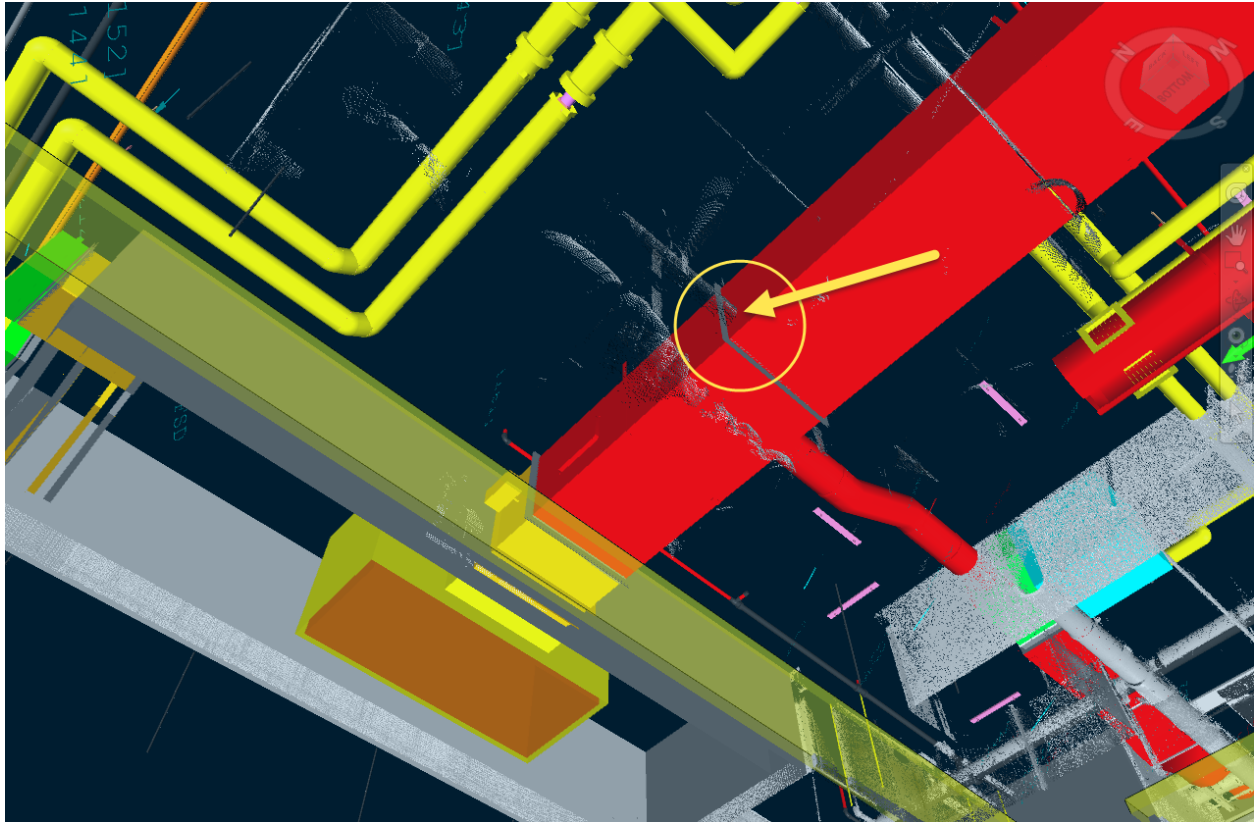


Figure 3 View of model and point cloud showing clashes between modeled elements and existing conditions.

3D point clouds offer an accurate 3D representation of existing-to-remain systems. While software developers have developed solutions to improve the process of using point clouds, capturing the most value from point clouds remains time consuming because many issues still need to be discovered by intentionally navigating to them, as opposed to being revealed automatically via clash detection tools

Automation is Here

As laser scanning becomes more and more common on construction projects it can be expected that leveraging the point cloud data would become the focus of savvy software developers.

Three such developers have created powerful software to help you save time and get the most out of your point cloud data. *BuildIT Construction*, *Skur* and *Clearedge3D Verity* are examples of software designed to detect and report the variances between point clouds and building information models. With varying features, integrations, and pricing models the recommended solution highly depends on your project objectives. These solutions can greatly decrease the time of analyzing point cloud data compared to manual methods and all provide exciting insight into what is possible with laser scanning.

like Navisworks or BIM 360 Glue.

Don't just go out and get a point cloud without some basic knowledge about laser scanning. It's important to define expected results from the use of 3D point cloud data. For instance, **when** the point cloud is captured might influence what it can be reliably used for. For instance, point cloud data captured before demolition on this project might have been adequate for confirming placement of structural systems and openings in shear walls. It also included irrelevant content planned for demolition and omitted existing systems to remain obscured during the laser scanning, making the data inadequate for detailed overhead system coordination.

Part Two: How to find and evaluate a Building Documentation Professional

Once you have decided that laser scanning can benefit your project, step one in the Building Document Professional (BDP) procurement process is to choose the specific types of services you need. Specify them in an RFP (Request For Proposal), before you look for the right BDP partner to provide those services.

Possible BDP services

Check construction progress against the design

When individual scans are placed into a BIM or CAD environment, the dense scan data makes design problems easy to visualize. If problems are identified, the scan data can be used to provide measurements to the design team, so the design team can revise the design to avoid future conflicts.

Construction Validation

Laser scans allow you to check a specific aspect of construction and mine information so that corrective action can be taken if needed, like evaluating the flatness of a concrete slab. Point clouds can use colors to reveal any high or low areas in the pour. The extents of these areas can be established, and distinct points can be derived and then uploaded to a total station for staking out locations in the field. Additionally, the volume of material needed to fill in the low areas can be calculated from the laser scan

Quality Assurance Validation

Automated quality assurance tools provide valuable insights that help contractors plan better and head off problems before they materialize on the job site. One of the simplest and most valuable laser scanning applications is scanning during the construction process to validate that the work put in place is as designed. Without the context of building elements yet to be installed, the naked eye may not be able to detect many construction issues.

Validate Work Complete

Laser scanning is currently one of the fastest and most accurate ways to capture the job site's existing conditions to evaluate work on a daily or weekly basis to assure the best quality construction. For example, owners can compare actual construction using laser scans with the BIM 4D proposed construction timeline for validation of pay apps by registering the point clouds together and oriented to match the federated BIM.

Validate Model Content

Point cloud data can also be consolidated with the model geometry and either visually analyzed or evaluated with automated tools to identify clashes and deviations (areas where model geometry exists but no point cloud data, or vice versa). When deviations or clashes are identified, the team can investigate the as-built point cloud and the federated BIM to validate the source of the problem and find a solution before it affects the budget or schedule.

Renovation as-built scanning

As-built drawings are often inaccurate, incomplete, or do not exist. If a building renovation or retrofit is designed based on outdated or incomplete drawings, errors could be inadvertently “designed in” and remain invisible until the construction phase, when they are very expensive and time consuming to fix. The best way to avoid these surprises during construction is to perform 3D as-built scanning to capture

Level of Accuracy

How does your BDP partner identify the accuracy of the data or models? Consider utilizing the USIBD’s Level of Accuracy (LOA) Specification. The USIBD’s LOA utilizes a tiered scale approach, similar to the AGC’s (Association of General Contractor’s) Level of Development (LOD), as a reference or guideline to enable professionals AEC Industry to specify and articulate, with a high level of clarity, the accuracy and means by which to represent and document existing conditions.

the complete information about the space to be renovated.

Often referred to as “scan to BIM”, this process can reduce the time required to build complex 3D models of existing real-world items.

After point clouds are registered or stitched together, they are oriented to match the coordinate system of the drawing or model so both sets of data align. Then, the as-built scan data can be compared to the existing drawings or models. The drawings and models can be adjusted to match the scan data, so the team can begin to design. If no models or drawings exist, the scan data can be utilized as a starting point for creating the new documentation. Isolating point cloud data is a great way to model or draft on top of point clouds. The point cloud can be sectioned horizontally to expose a plan view that can be traced in a BIM authoring tool to create very accurate floor plans, or it can be cut vertically to provide elevation or section views for tracing.

As-Built Model Production

There are several “scan to BIM” platforms offering semi-automated development of 3D models based on laser scan data. CloudWorx and Edgewise are great examples of software which features the ability to derive smart 3D geometry from point cloud data. Existing architectural, structural, and MEP components can be modeled in a fraction of the time compared to manual workflows.

Validating As-built models

The same process discussed above can also be used by General Contractors to validate the quality of the As-built models provided by their sub-contractors at the end of a project, ensuring that the models turned over to the owner are accurate and reflect as-constructed conditions.

Boundary & topography surveying

Laser scanning can be used to collect data points for property and topographical point clouds that can also be converted into models. Note: it is important to verify with your local jurisdiction whether a licensed Professional Land Surveyor (PLS), or Civil Engineer legally must perform these services.

Unmanned Aerial Vehicle systems (UAVs)

Another way to capture the data needed to create 3D topo or building models is to use unmanned aerial vehicles (or UAVs). When stakeholders can look at clear, accurate and detailed representations of a piece of land or a facility, planning becomes easier, knowing that any assumptions they make are accurate. UAVs work faster than traditional surveying teams and use the latest technologies to capture

Converging Tech: Greater than the Sum of Its Parts

UAV Aerial photography alone has proven to be a valuable tool on construction projects in recent years. With photogrammetry software, such as Pix4D, Skycatch, or Drone Deploy, UAV data can be leveraged even further. Photogrammetry enables the creation of 3 dimensional point cloud data similar to that captured by a scanner. While the resulting point cloud is not as accurate as laser scan data it can be useful for verifying site work, comparing to project BIMs, and calculating excavation and spoils volumes.

detailed and accurate land or building data.

Subsurface Utility Engineering (SUE)

Subsurface utility engineering (SUE) can be used to help manage the risks associated with underground as-built utility mapping.

What are your data needs?

Knowing how the laser scanning data will be applied is key to identifying the right solution and the necessary deliverables. Before evaluating hardware and software or comparing BDP proposals, consider the following:

Laser scanning can obtain high definition data sufficient to show fine detail such as bolt patterns on steel pipefittings. Many software packages have built-in libraries where actual sizes of steel and/or pipes can be identified and modeled directly from the point cloud. Libraries of shapes or grouped models can be made and used throughout the site. The point cloud can also be used to create paths with the correct clearances to remove large equipment from the site once construction is complete.

What are your data deliverables and formats?

- Building Information Models (Scan to BIM) in RVT, STP, IGES, SAT, DWG, DXF, IFC, PLN, VWX
- Exact Surface 3D models in IGES, STP formats
- Parametric solid 3D models in SLDPRPT, SLDASM, IGES, STP formats
- 2D drawings in DXF, DWG, PDF, SLDDRWF formats, DGN
- 2D topography mesh in DTM, DXF, DWG, STL, OBJ, X3D formats
- Scans in STL format
- Point Cloud in XYZ, PTS, PTX, E57, RCP/RCS and other formats
- 3D-print compatible STL files

- 3D Photo, orthophoto or ortho-rectified images in TIF, PNG, or JPG formats
- Videos and animations such as 3D walk-throughs and fly-throughs
- Panoramic views
- Inspection reports
- Deviation images

Unique questions to ask the BDP

Does the BDP use the latest technology and produce survey-grade data?

One of the biggest challenges when trying to hire a BDP is separating the hobbyists from qualified professionals. For example, in aerial surveying, as UAVs become less expensive over time, more and more people are starting to think they have the technology and experience it takes to perform surveying services. However, there is a clear difference between the work of experienced UAV operators flying the latest technology, and the work of amateurs or hobbyists.

Contracting a Building Documentation Professional will help ensure you receive high quality, survey grade data from which you can make informed decisions based on accurate information. While BDPs and hobbyists alike can obtain and use the latest technology, what truly separates the BDPs from the hobbyists and amateurs are the processes and proven workflows that can only be developed through experience over time.

Does the aerial BDP employ certified UAV operators?

The UAV space has long been subject to government regulations. While these regulations have made life a bit more difficult for people looking to source data quickly and cost-effectively, they are also necessary to ensure that UAVs are operated safely. Cutting corners by hiring someone who isn't a UAS-certified UAV pilot may not seem important at first, but the consequences of such a decision could come back to haunt you. If a UAV operator doesn't follow all applicable laws and guidelines, as well as have the proper liability insurance while working on your project, your company may face legal complications as a result. Hiring a certified UAV operator is the best way to avoid these kinds of problems.

Is the Building Documentation Professional an end-to-end service provider?

After a BDP collects your project data, then what? Will they simply deliver a data dump and expect for you to handle the rest? Ideally, you should work with an end-to-end service provider that not only helps you gather your data but also helps you use it appropriately.

The process isn't complete until the data has been fully processed and stored. An end-to-end service provider can ensure that this happens. Such a partner not only makes sure your data is stored securely, but additionally, it makes sure that you can access the data when needed.

Ask for examples of projects like yours

When you have narrowed down the top two or three BDPs, ask each of them to provide a list of recent projects they have completed like yours. From this list, ask them which two or three projects they are willing to offer as references and share contact information. Contact each reference to discuss how each project was successful and what could have been improved.

Use the USIBD RFQ template

To ensure you are engaging with qualified BDP's, the USIBD has created a Request for Qualifications template that can be customized for your project. It is available for purchase here:

<http://www.usibd.org/store>

Use the USIBD RFP template

To ensure you obtain apples-to-apples bids, the USIBD has created a Request for Proposal template that can be customized for your project. You should use this template as a starting point, and modify it as appropriate for your specific needs and project. The template is available for purchase here:

<http://www.usibd.org/store>

Obtain a list of BDPs in your area

To start your procurement process, contact USIBD at 833-874-2348 [833-USIBD 4 U] for a list of BDPs that are USIBD members in your area. While USIBD members are encouraged to network among the membership, you should not shortcut your retention process by not asking the right questions of prospective BDPs so that the needs of your specific project are met.

Part Three: How to identify clashes between point clouds and solid geometry.

As point cloud data becomes available during construction phase BIM coordination, it is important to understand what one can do with it. Solid geometry can clash against point clouds with accuracy within Navisworks. The steps below explain how this is done.

What you need to follow along.

1. A working version of Navisworks Manage
2. Step files available from the link at the QR code below

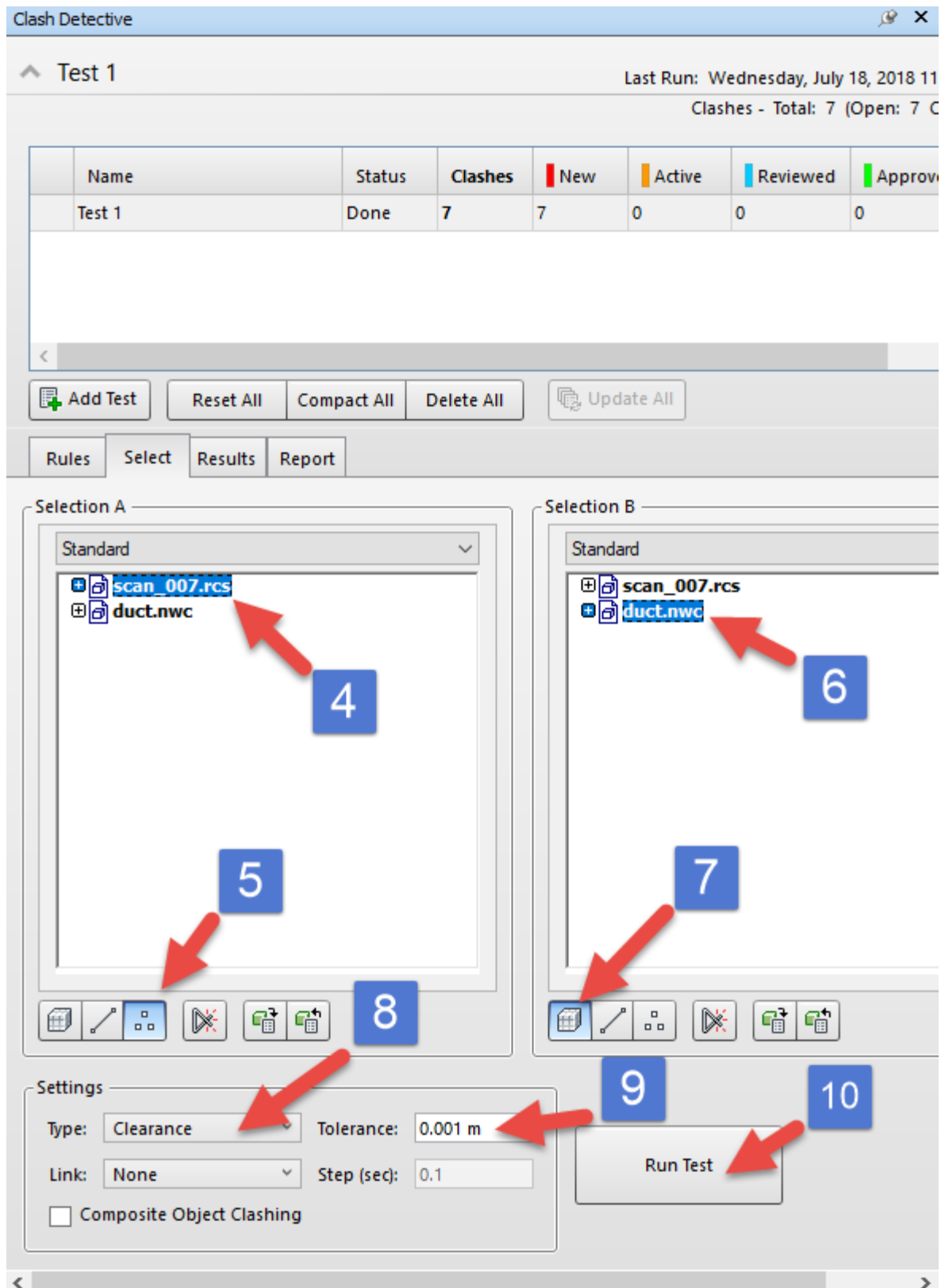


Steps

1. Download the three files available at the QR code above and put them in a folder of your choosing
2. Open “pointcloud clash.nwd” in Navisworks Manage
3. Launch Clash Detective

Refer to numbers in the attached image corresponding to steps below

4. Select “scan_007.rcs” in one pane
5. Set it to clash points
6. Select “duct.nwc” in the other pane
7. Set it to clash surfaces
8. Under “Settings” Select “Clearance” under the “Type:” drop down
9. Set the “Tolerance” to 0.001m
10. Run the Clash Test



After running the clash analysis, select the Report tab to view the clashes found like the list in [Figure 6](#)



below.

Name		Status	Found	Approved...	Appi
● Clash1		Active	▼	11:55:35 18-07-2018	
● Clash2		Active	▼	11:55:35 18-07-2018	
● Clash3		Active	▼	11:55:35 18-07-2018	
● Clash4		Active	▼	11:55:35 18-07-2018	
● Clash5		Active	▼	11:55:35 18-07-2018	
● Clash6		Active	▼	11:55:35 18-07-2018	
● Clash7		Active	▼	11:55:35 18-07-2018	

[Figure 6](#)

Clash 1 will look like [Figure 7](#)

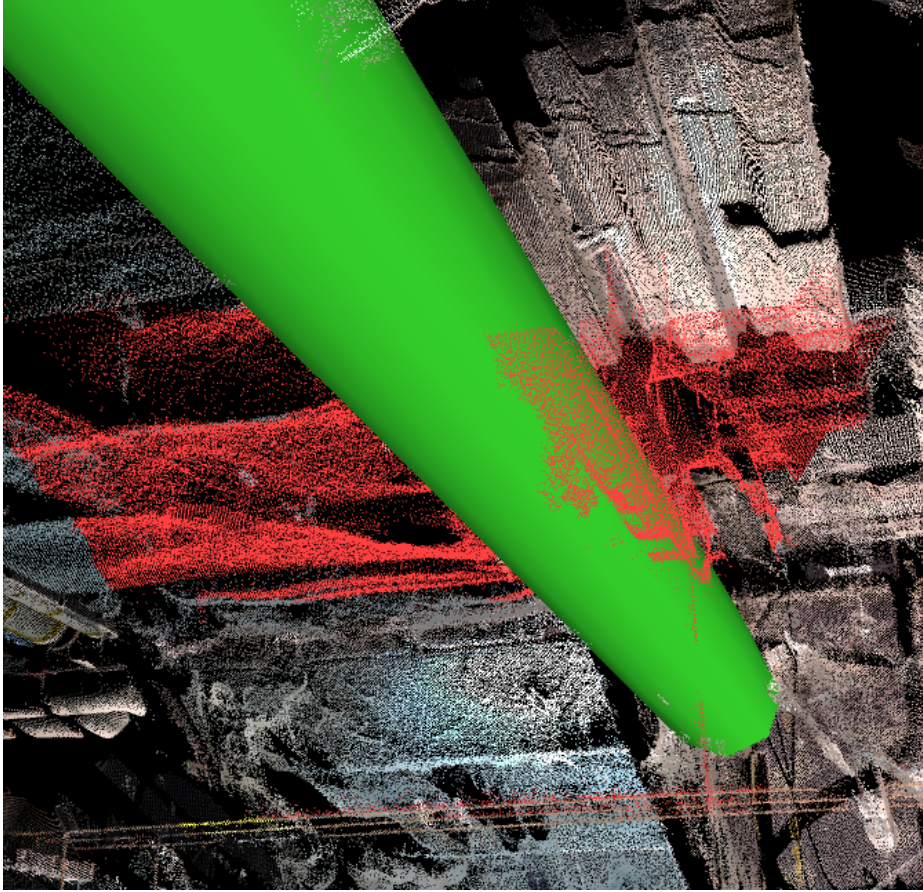


Figure 7

Thanks for your interest in the USIBD and for taking some time to read this paper. By now you are familiar with the challenges inherent in using scan data. Knowing what you plan to do with the scan data before acquiring it is key. An investment in training and equipment might support your desired use case. You know what criteria to consider when hiring a Building Documentation Professional. Also, you are ready to practice some simple work flows using common software in the AEC field. Finally, consider joining the USIBD. The USIBD is a network of support and information for the Building Documentation Industry.