AUTODESK UNIVERSITY 2014

Adopting Reality Computing for Plant Design

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PD6732-P Over the past few years point clouds have gone from novelty to design requirement. During this time many companies have encountered technological limitations due to insufficient hardware and software solutions. Much has changed. The reality computing technology from Autodesk, Inc. is making laser scan data easier and more efficient to use than ever. This class will examine real Autodesk user experiences regarding how these firms are successfully implementing point cloud data for plant design. Gain insight on the software used, the growing pains experienced in introducing new technology and the workflows adopted to help users get from the field to completed design. This class will also recommend favorable workflows within Plant Design Suite 2015 software. Discover how to achieve typically needed plant deliverables, including catalog piping and structural design, tie-in point extraction, clash reporting, isometrics and equipment analysis all from native Autodesk point clouds.

Learning Objectives

At the end of this class, you will be able to:

- Learn how to adopt point-cloud workflows within the 2015 Plant Design Suite software
- Gain insight from user experiences regarding what to expect with new Autodesk technology
- Understand the recommended steps for preparing laser scan projects within your Autodesk design package
- Discover how to extract typically needed plant deliverables from point clouds, such as intelligent models, tie-ins, and more.

About the Speakers

Scott Diaz is director and owner of kubit USA in Houston, Texas. Over the past 7 years Scott has been promoting, developing and teaching Autodesk based reality capture and reality computing workflows throughout various industries. He and his team have setup major reseller relationships throughout the US which support kubit's efforts in offering AutoCAD and Revit based products for as-built capture and design. Scott has a background in business management and marketing with an MBA from Lamar University. He worked previously as technical marketing manager for an Autodesk 3rd party developer focused on industrial facility design.

John Bunn is director of technical sales for kubit USA and an assistant product manager for kubit globally. He is the top technical contact for the software in the Americas. John has more than 16 years of AutoCAD experience as a user and professional programmer with specialty knowledge in the industrial facility/piping design space. He is an expert level user and trainer of point cloud design and modeling within the AutoCAD environment.

Contents

Adopting point cloud workflows for Autodesk Plant Design Suite 2015

What is Reality Computing as related to plant design?

Autodesk defines Reality Computing with three simple terms; Capture, Compute, Create. What does this mean and how does this translate to the world of industrial facility and plant design?

Capture

Capture has a similar definition across most industries and refers to collecting existing field conditions with the use of surveying instruments and/or digital cameras (photogrammetry). In the plant design world these instruments are typically terrestrial laser scanners. Figure 1 below demonstrates the basic process of laser scan data collection.

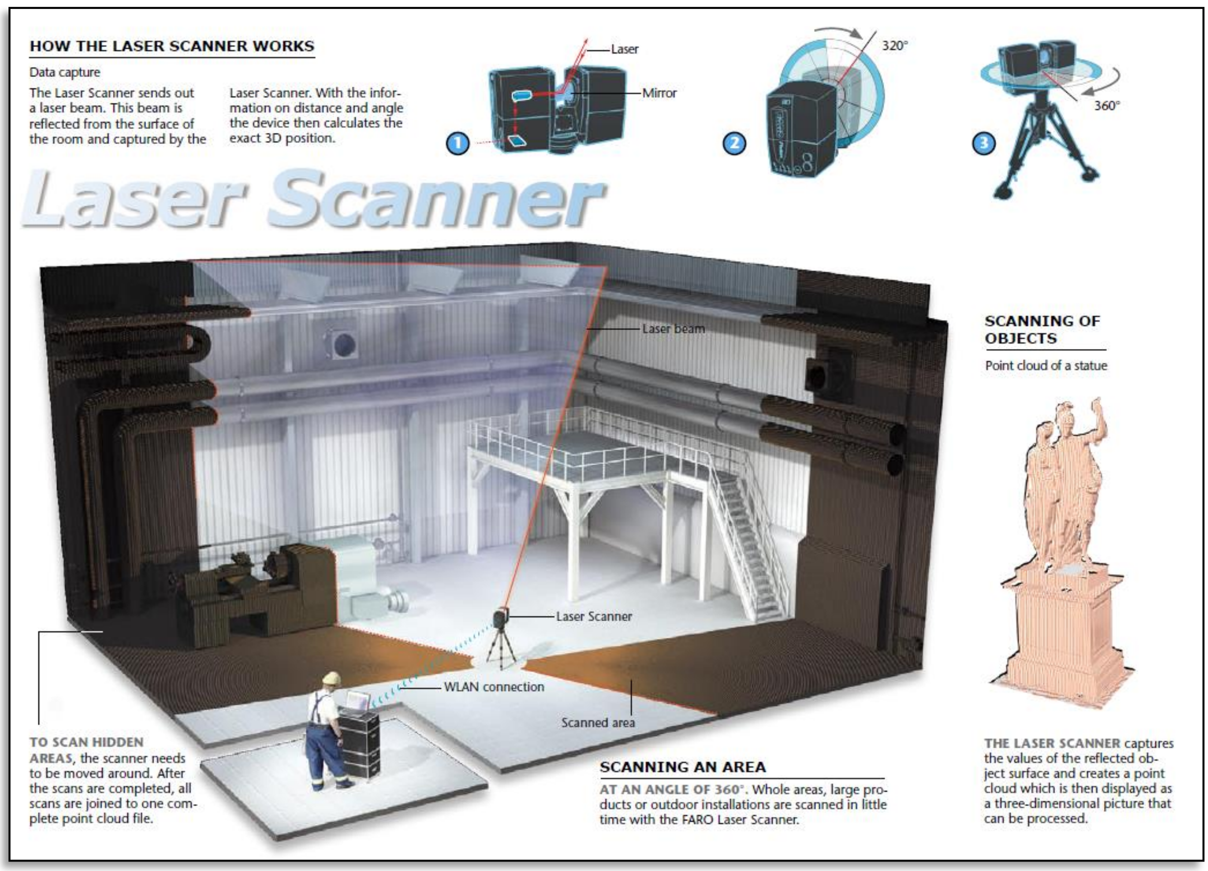


Figure 1: Laser Scanning Process

Although terrestrial laser scanners have become an accepted means of data collection, today we are seeing the emergence of image based technologies which use multi-view photogrammetry or structure from motion technology (in combination with powerful servers) to generate point clouds from photos. Will these less costly devices replace traditional scanning technology or simply enhance existing methods? Because scanning in the industrial environment typically requires tighter tolerances and higher levels of accuracy these additional technologies may require further development and/or research before they are accepted as “accurate enough” based on the desired deliverables required.

Figure 2: Capture devices from left to right: FARO Terrestrial scanner, DOTProduct multi-view photogrammetry and traditional structure from motion via digital camera

Compute:

The computing portion of Reality Computing refers to processing acquired data into a useful form. For plant design this means first registering the data into an organized structure and coordinate system. Afterward users begin the post-processing phase which converts organized data to typically needed design deliverables.

Registration

During a complete project the laser scanner is usually placed on multiple positions to get a complete documentation from all sites. Every single scan creates a single 3D point cloud.

In a next step each individual point cloud is registered to each other. As a result of the registration process one point cloud data set within one coordinate system is created. This registered point cloud is now ready to use for evaluating in AutoCAD.

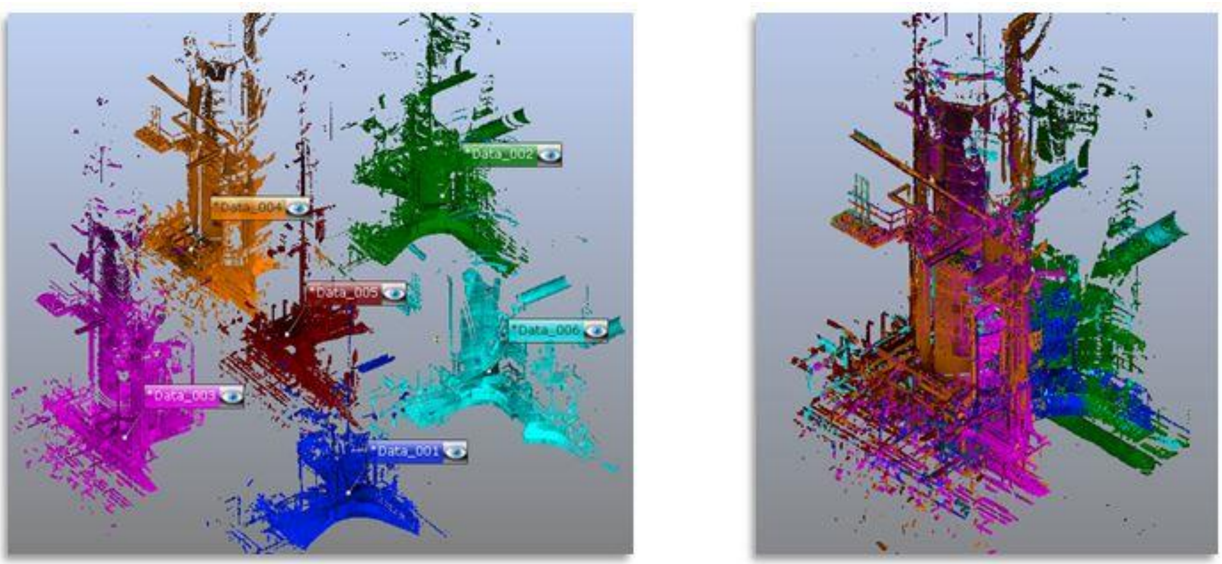


Figure 3: Individual scans become one registered cloud

To register the individual scans together identical objects in each scan are needed. Depending on the covered object and the needed precision this is usually done by placed targets. The targets need to be placed on site before the scanning process starts so that they are part of the point cloud.

An alternative to targets is to use natural objects (planes, corners, etc.) within the scan as reference objects for the registration process.

Create

When Autodesk mentions the “create” portion of Reality Computing they usually refer to 3D printing and digital prototyping. This means reproducing a physical object from data collection, but what does “create” mean for plant design? To put simply “create” is referring to traditional plant deliverables for engineers. These can include but are not limited to

- Asset management reports
- Intelligent modeling (ex: AutoCAD Plant 3D or Autodesk Revit),
- Tie-in point extractions for plant turnarounds,
- Generation of isometric shop drawings,
- Collision detection reports between proposed and existing structures
- Existing equipment condition reporting.

All of these results and more can be derived from laser scan data and represent CREATE for reality computing in plant design. Discussed later are methods for generating these results.

Mentioned above is a description of new hardware devices which will become more commonplace in data capture. What is trending in software? For years, software lagged behind the capabilities of capture devices. It lacked the ability to handle large volumes of data or provide a user friendly means of generating something of use from millions of points. One major change is the creation of powerful, new point cloud engines which are now allowing massive data set handling within traditional design programs like AutoCAD. Data registration is becoming a more automated process, less cryptic and with fewer expert level requirements. Finally, post-processing and extraction software packages are allowing for more automated extraction of intelligent models and key reporting without so many manual steps. Below is a list of what Autodesk has improved for AutoCAD 2015 point cloud users.

- Improved graphics engine: One of the biggest issues with point clouds in AutoCAD 2011-2014 is the lack of viewing quality. The more points, the lower the viewing quality. This was necessary for AutoCAD to be able to handle such large files. With the 2015 release, users are now able to view 100% of scan data on screen through various options and the default value of viewable points has increased dramatically. Visualization has made point clouds more user friendly.
- 64 bit only and quality graphics card: Only 64 bit versions of AutoCAD support point clouds and Autodesk recommends a dedicated video card to benefit from the full power of the engine. More info can be found at http://usa.autodesk.com/adsk/servlet/syscert?id=18844534&siteID=123112.
- RCP/RCS files: Prior to 2015 the PCG file was the more common file format used for supporting cloud data in AutoCAD. This file format is now a legacy format for older drawings. Autodesk has moved to fully support the RCP/RCS file formats generated through Autodesk ReCap.
- Point Cloud Manager: Attaching a point cloud project file (RCP) to AutoCAD now gives users the ability to visualize scan positions and regions as they are accessed within the ReCap program.

Now users can turn positions on/off or navigate to scan view. Isolating scan positions also improves overall viewing quality on large projects.

From Field to CAD:

Since 2011 Autodesk has supported point clouds natively. The best workflow for inserting point clouds to the design environment and managing data sets has changed slightly each year. With the release of Autodesk 2015 products, the recommended workflow has reached a consistent point and will remain so into the future. This is a relief for current users and trainers. The following steps describe the recommended workflow from field to AutoCAD.

Importing data to AutoCAD

1. Scan in the field: No change to this process. The user scans in each position where data is required. Scan strategy based on desired object capture is discussed later in the document.
2. Bring data to registration software: See "registration" section above. Plant users may also register data to the plant north coordinate system at this time. Laser scanners typically come with their own manufacture's software for data registration. As an alternative, Autodesk users may choose to use Autodesk ReCap Pro. The Pro extension of ReCap was introduced in the 2014 release and allows users a simple alternative for connecting scan positions into an organized coordinate system through simple region matching between scan positions. The image below displays region matching between two scan positions in ReCap Pro.

Figure 4: Scanorama view in Autodesk ReCap Pro

3. Import data to Autodesk ReCap: Once the data has been registered, users may import the resulting set into Autodesk ReCap. This program accepts scan data from the majority of major scan manufacturers as well as common, open formats and converts the files into Reality Capture Scans (RCS files). It is recommended to use a file format which allows for individual scan position

control after import to the Autodesk world. As an example, if the surveyor scanned 10 positions in the field, 10 RCS files should be created upon import to Autodesk ReCap. For this reason, PTS and ASCII or other unified data sets are not recommended. This import process converts each scan position to an RCS file and the project saves as a Reality Capture Project (RCP) which references each RCS scan position. These files are now ready for use throughout the Autodesk design products which support point clouds (AutoCAD, Revit, 3D Studio Max, Navisworks, etc.).

4. Attach RCP to AutoCAD: Click the INSERT ribbon and choose to ATTACH a point cloud. Select your RCP file and scan data will import to AutoCAD. Click on the point cloud to reveal additional options. Notice the Point Cloud Manager option. Here you will see the list of RCS scan positions which make up your RCP project from Autodesk ReCap. Turn positions on, off or navigate to scan positions freely by double clicking the scan position in the list.

User Experience: Reducing Turnaround Time

Eric Kirsch of Jacobs Engineering shares first-hand experience on how laser scanning has saved thousands and potentially millions of dollars in plant down-time during turnarounds.

Background:

Eric Kirsch is piping design supervisor for Jacobs Engineering in Costa Mesa, California. He has worked as a piping designer and supervisor for more than 24 years and began using laser scan data in 2008 for visualization but outsourced as-built modeling and post-processing of scan data to 3rd party firms. As competitors began to offer in-house services, Eric finally convinced his supervisors to employ laser scanning and scan services in-house. The team decided on a combination of AutoCAD 2010 and CADWorx for the design deliverable. To mend the gap between point clouds and CADWorx model, the team began using kubit's PointSense Plant product.

"We needed a product which allowed us to more easily convert the scan data into useful plant objects. We also preferred that the program function within AutoCAD. PointSense matched our needs."

The early days of scanning and post-processing were no easy task. Scan data visual quality was poor and machines had limited storage space for so many scan file formats. Users were also completely new to working with scan data so the learning curve was higher.

Eric's team began creating as-built models for many of the initial projects. Over time, they realized that clients did not always demand this as a deliverable. Because modeling the cloud was a fairly time consuming process, he and his team decided to focus on the extraction of key tie-in points in the scan data and only model what was necessary.

Project Scope:

Within the live presentation, Eric shares how he and his team were tasked with increasing the water volume requirements from an existing tank in their facility. This would require replacing existing suction and discharge piping to/from existing pumps. The team would need to install a new 30" nozzle on the existing tank and would attempt to pre-fabricate all of the new design in the shop. The objective was to install all of the fabricated items within a 24 hour shut-in time.

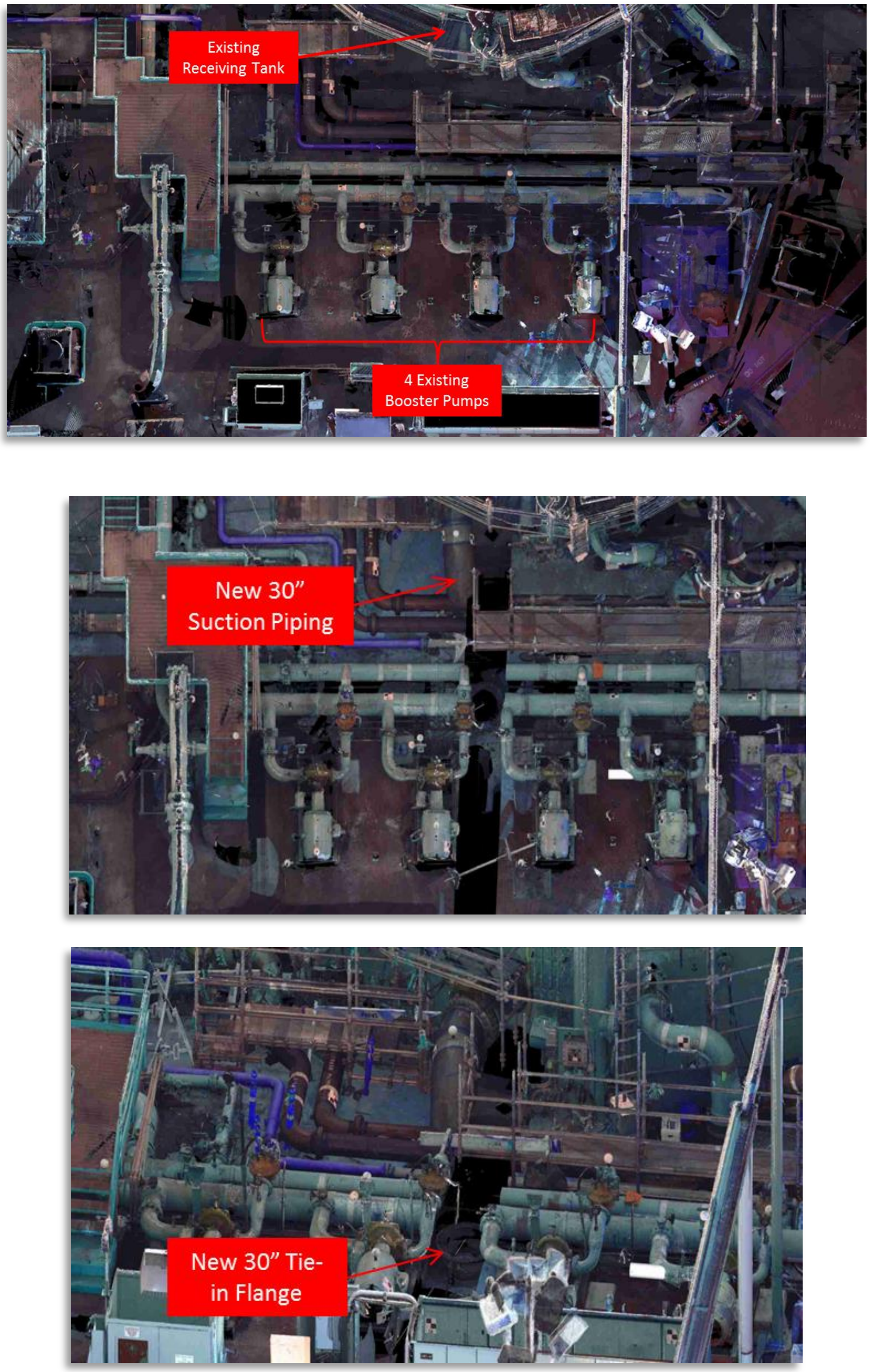


Figure 5: Identifying key tie-in points

Action Plan:

Here are the steps taken by Eric and his team to complete the project

- Laser scan 22 positions with a Faro scanner
- Registered scan positions within Faro's Scene software
- Using AutoCAD 2013 at the time, the team indexed scan files directly to AutoCAD PCG format
- Import to kubit's VirtuSurv product to enhance viewing quality of scan data
- Begin identifying and extracting tie-in points via PointSense Plant
- Model new pipe runs based on existing conditions and send to fabrication.
- Scan new piping in fab shop to identify tie-in points
- Check for interferences and ensure that newly created piping fits into the existing plant conditions

Figure 6: Mock-up scan of fabricated pipe to be placed in field

Challenges:

During the process, the team's biggest challenges were

- Unexpected revisions /add-ons to the original project plans. This caused an already complex job to become more complex due to additional demands by client.
- Integration of multiple new scans: Tying the scan data from the fab shop to the real world required some expert knowledge of surveying. For this, Eric called in some professional help from licensed surveyors to make sure accuracy was in place
- Tight scheduling requirements: The downtime in this plant per day was estimated at $1 million per day. Needless to say, the pressure was on the team to complete the job in a timely manner.

Project Summary:

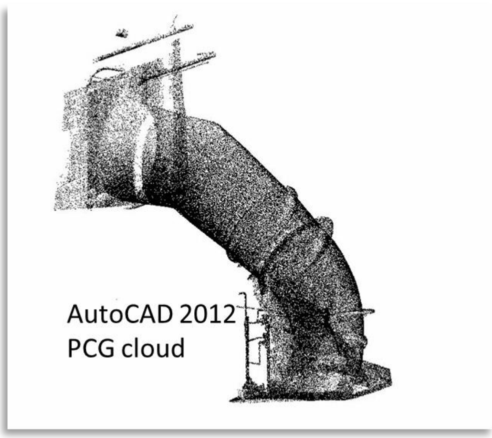
The project completed successfully 10 hours ahead of schedule and also eliminated pump cavitation. Eric estimates that approximately $500,000 was saved in production time alone thanks to laser scanning and the right set of tools.

Figure 7: Craning in new pipe and ensuring fit to flange. Image 3 shows new piping next to previous demo piping.

A Look to the Future:

Eric's workflow has changed over time as the team discovers what workflows are most efficient based on client demands. In addition, software continues to improve making a significant impact on ease of use for current/new users as well as reducing overall field to deliverable time.

"We recently adopted AutoCAD Plant 3D 2015 and the difference in visual quality is stunning. It allows us to better navigate and visualize cloud data as well as do more with our PointSense software."



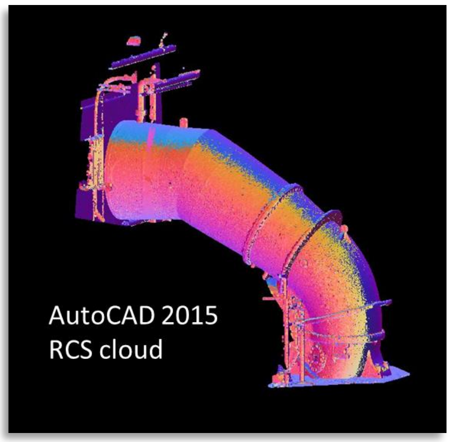


Figure 8: Viewing quality comparison

User Experience: From Scan to Intelligent Models

Rod Kreiss works for Performance Mechanical, Inc. in Pittsburg California. Among many other services the company specializes in plant turnaround work for major OEM facilities. Rod heads up the laser scanning department and has become a strong advocate for the technology in the past years. With many hundreds of successful laser scan jobs completed, Rod receives requests for deliverables in all formats including

- Raw point cloud delivery
- As-built piping/structural modeling
- Tie-in point extraction
- Interference detection
- Intelligent piping design

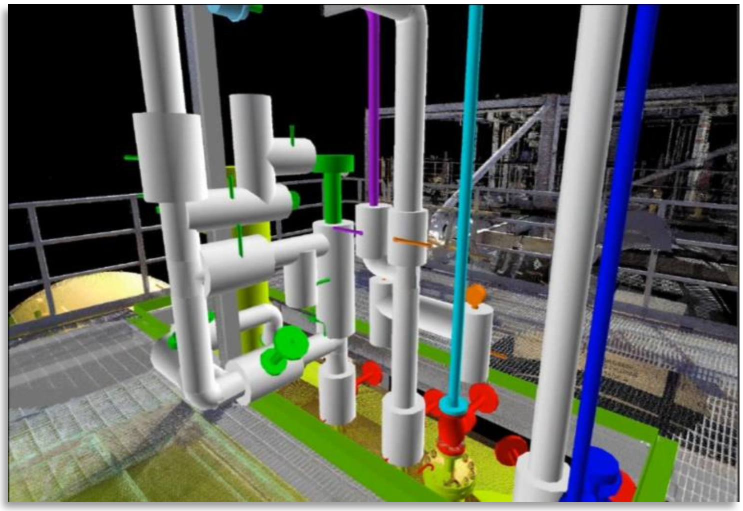


Figure 9: Generic level of detail model with cloud

"When clients request as-built models be prepared to collect a detailed scope of work. Miscommunication is rampant because clients often miss the details behind modeling possibilities and options. More detail equals more time which results in a higher cost. It is important to give the client options and let them know expectations in advance."

Detailed Scope

Some points to keep in mind for as-built models are:

- Model level of detail: Generic representation of objects or closer representation of reality (Examples of low, medium and high detail help describe the point)
- What needs to be modeled, what doesn't? (ex: Any pipe larger than 2" and all structural steel members. Avoid cable trays, conduit and ground.)
- Intelligent models: Is the result for the client for their intelligent piping program or do they require simple solids?

Reasons to Model

Rod uses AutoCAD Plant Design Suite 2015 and kubit's PointSense Plant for extracting as-built models from the point cloud and converting them to AutoCAD Plant 3D. Although tie-in points and clash detection are often effective methods for assessing the as-built condition, sometimes modeling is essential. Rod states "this work is not possible without quality software tools. PointSense Plant allows for modeling what we want and avoiding what we don't. All extraction is spec driven and these come directly out of our Plant 3D spec editor so there is no time wasted in recreating catalogs. In the end kubit allows us to generate Plant 3D intelligent models automatically from the extracted shapes. We use Plant 3D for new design, building the asset management database in a facility and running all intelligent reports based on these field assets."

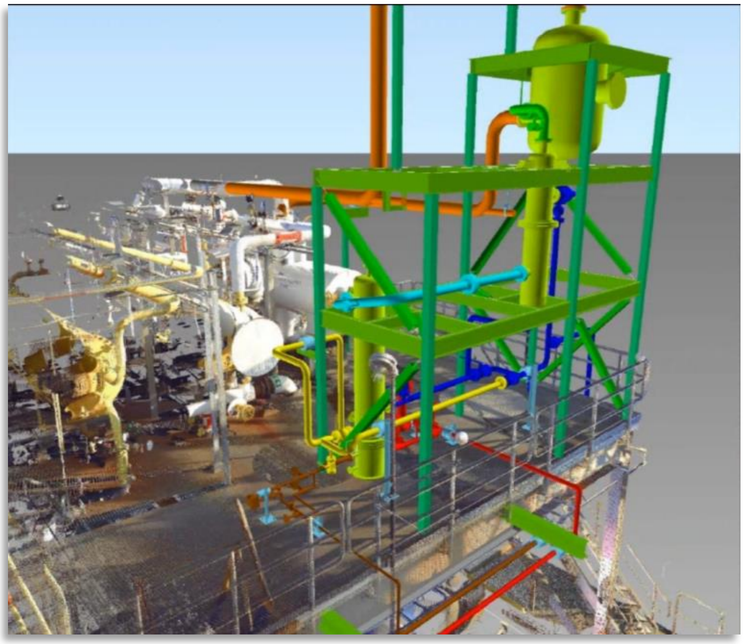


Figure 10

"Typically clients request models for one of a few reasons. First, point cloud files are still large, bulky files which not everyone wants to manage or are comfortable using as a representation. Clients just need the information in the format which fits to their current system. This is usually as solids or an intelligent design format (Plant 3D, CADWorx, PDMS, etc.). Second, using the cloud for clash detection is really great but sometimes scanners are not capable of capturing 360° around an object such as pipes and structure. In these cases, the only way to ensure that new design is not clashing with field conditions is by modeling the as-built. Finally, there are still numerous facilities which either extremely outdated or no facility documentation. These customers need help in building an asset management database from their facility. Point clouds need to be converted to parametric design."

Tips and tools for extracting plant deliverables from scan data:

This section describes how to create typical plant deliverables as listed in the "Create" portion of Reality Computing.

Piping design from point clouds

The creation of as-built models or tie-in points from point clouds requires shape extraction tools which pull geometry from patterns found in groups of point cloud points. Without pattern recognition algorithms in place, the modeling process is completely inefficient and inconsistent results are more likely. In addition, a piping designer needs more than primitive solids/surfaces to get to final deliverables such as intelligent models and accurate shop drawings (isometric, orthographic). For this reason, 3rd party software aids in connecting extraction algorithms to industry standard catalogs.

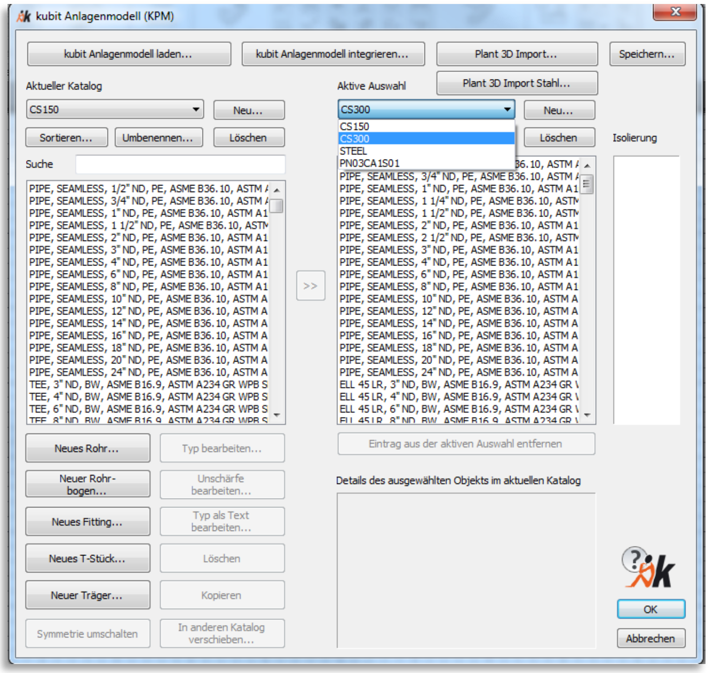


Figure 11: Example catalog to be used as reference during shape extraction

As-built Modeling

Once a catalog is in place as a guide for what is allowed into the model, the user can begin the intelligent modeling process. For example, a user extracts a cylinder shape with a shape extraction tool. The diameter of 8.39 inches is reported. This is ok if the user's job is to simply extract non intelligent geometry. The algorithm performs a best possible fit based on the points given. More intelligent software may reference this 8.39 inch cylinder back to the user's CS150 catalog and recommend an 8 inch nominal diameter pipe in place of the irregular shaped cylinder. Now the user has a catalog object instead of a useless solid.

Additional algorithms must be in place to help in the detection and placement of elbows, tees and inline fittings throughout the as-built modeling process.

Figure 12: Real world vs. Scan and model view

Matching Design Constraints:

The process for modeling objects from point clouds now seems fairly simple. With the right shape extraction tools and the correct reference catalogs the as-built model begins to form. Now comes the process of bringing the model into a traditional design deliverable. It is important to remember that the reference catalog is placing “perfect” catalog shapes over the imperfect real world conditions. As a result, gaps and misalignments occur when force fitting perfect objects into the point cloud. Design software such as AutoCAD Plant 3D and Autodesk Revit does not accept these misalignments and are not built to handle traditional brownfield environments. Such products expect connected objects, coaxial/coplanar axis’, 90°/45° angles, etc. Inserting a misaligned pipe run into Plant 3D would result in multiple, disconnected runs as well as the dreaded water drop symbols (indicating a missed connection). Before the runs are finalized they must meet the rules of the end software. This is the process of applying design constraints.

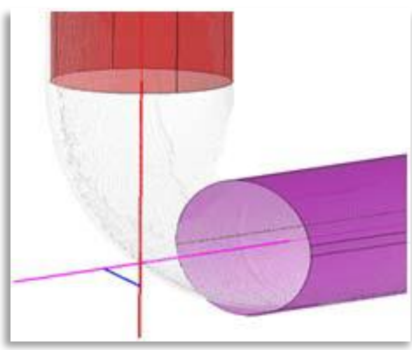


Figure 13: As-built pipe conditions. Cylinders do not intersect

A proper application of constraints aims to stay as close as possible to the points in the cloud and apply as few changes as possible to individually modeled objects while still meeting the rules of the final design software. An exaggerated model below shows the theoretical adjustment from as-built objects to a globally constrained pipe run.

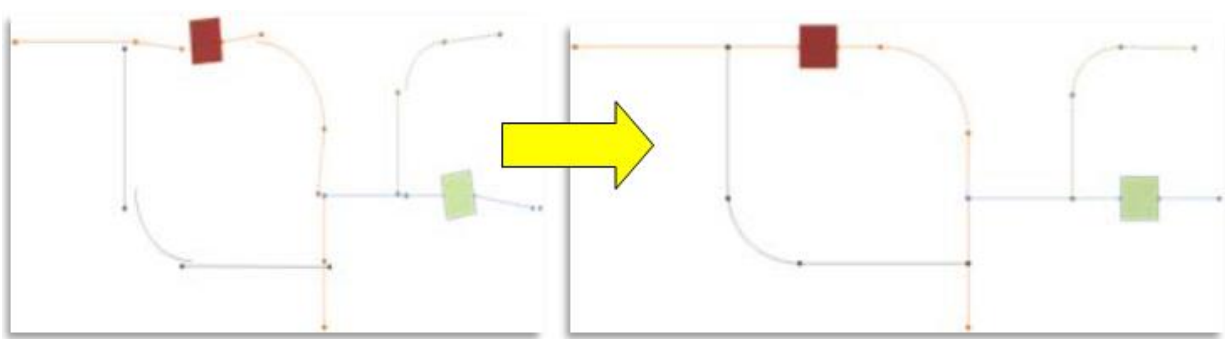


Figure 14: Applying design constraints

The constrained model is now ready for conversion into its final design software. Firms like kubit provide conversion tools which automate the intelligent Plant 3D object creation from detected pipe runs. Once converted these design software packages allow for asset management reports, isometrics/bill of material reports and more.

Tie-in Point Extraction:

Sometimes modeling a pipe run can be very time consuming especially if a designer only needs to derive specific tie-in points from specific pipe runs in the field. Why bother modeling everything in the point cloud in order to extract a few key points? There are different workflow options for users that have this need.

The user needs multiple options for deriving the tie-in points along a run. Based on the scan position, the user may only be able to see a flange or may only have scan data for the flange from a specific angle. For this reason, software must allow flexibility in calculating the internal tie-in points.

The most traditional method for extracting a tie-in point is by first extracting a pipe/cylinder in front of the flange of interest. This establishes a centerline axis. Stretching the cylinder to the face of flange or adding a flange to the end of a properly stretched cylinder will derive an accurate tie-in point. Unfortunately, not all flanges begin with pipes in front. What if the flange connects directly to an elbow or inline fitting? As shown below, a more advanced, catalog driven tie-in point routine could enable users to extract the needed location, tilt, roll angle and more simply by choosing a selection of points on or near to the flange.

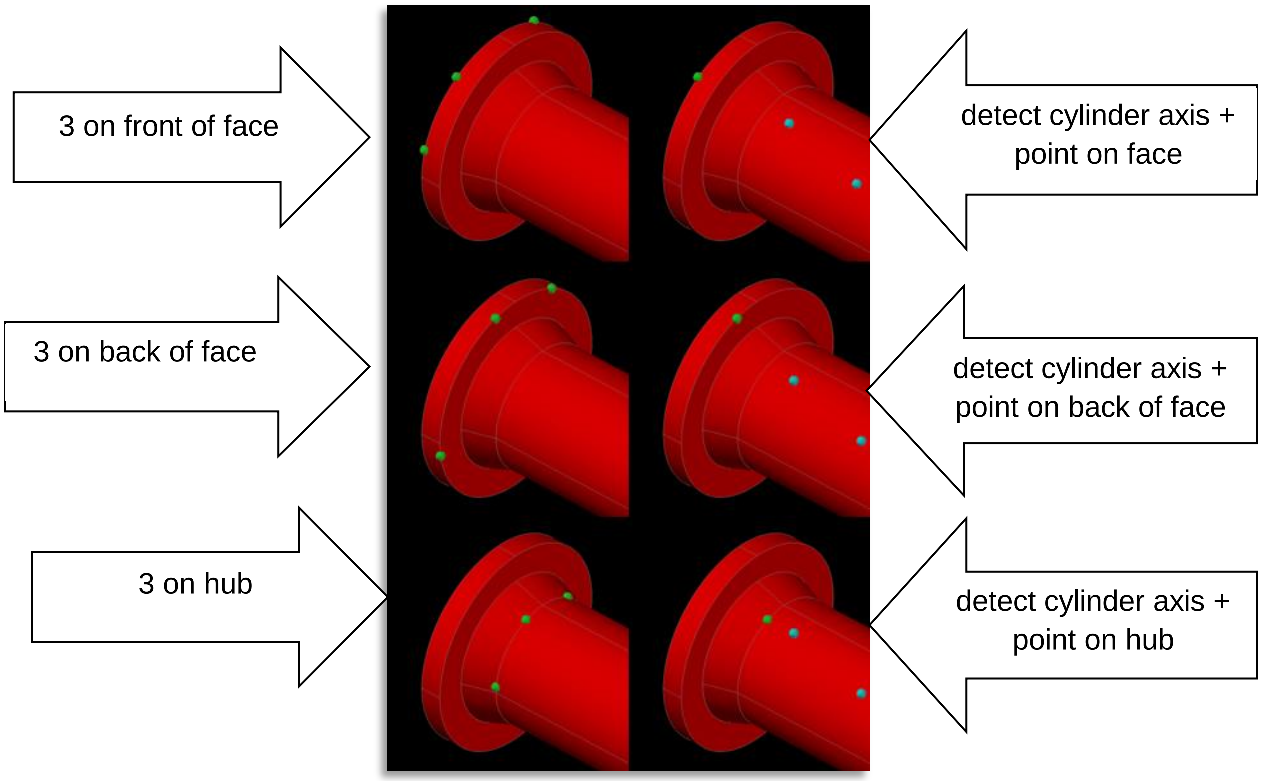


Figure 15: Tie-in point detection options

Structural design

Similar to piping the point cloud, structural modeling from point clouds uses intelligent pattern recognition algorithms for recognizing steel members by matching detected shapes to catalogs. Although similar, structural extraction poses many more challenges. A pipe carries a consistent cylindrical shape so algorithms need little more than 15-20% of a pipe to determine size. Structural beams carry a variety of shapes and faces.

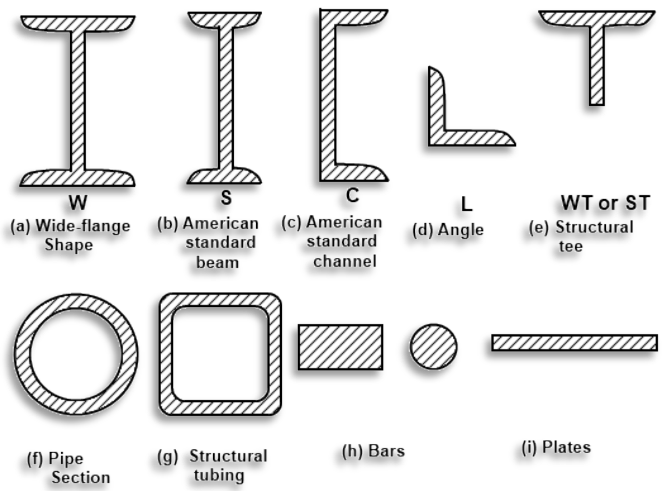


Figure 16: Structural profiles vary in size and shape

Scanning Structural:

A surveyor can scan pipe more carelessly than structural steel. If the desired deliverable is to determine the size/type and location of steel members, the capture device should pick up as many faces of the structure as possible. Take the figure below as an example. From one side the shape resembles a typical channel beam, but if scanned from an additional position, the data reveals that the shape is in fact a wide flange. Software cannot make this determination alone and can only suggest possible options. To avoid problems during the modeling process, it is recommended that the surveyor and designer have strong communication on what data is needed in order to complete modeling routines more efficiently.

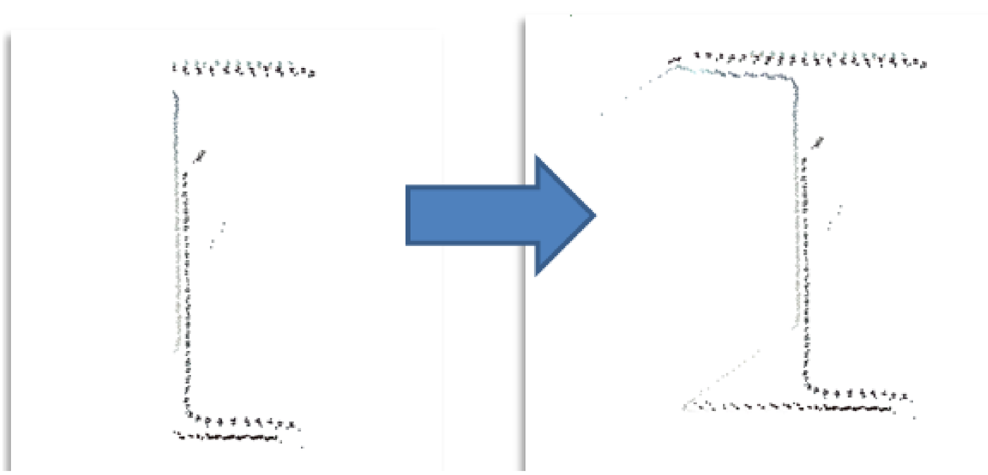


Figure 17: Capturing structure from multiple angles reveals the true shape

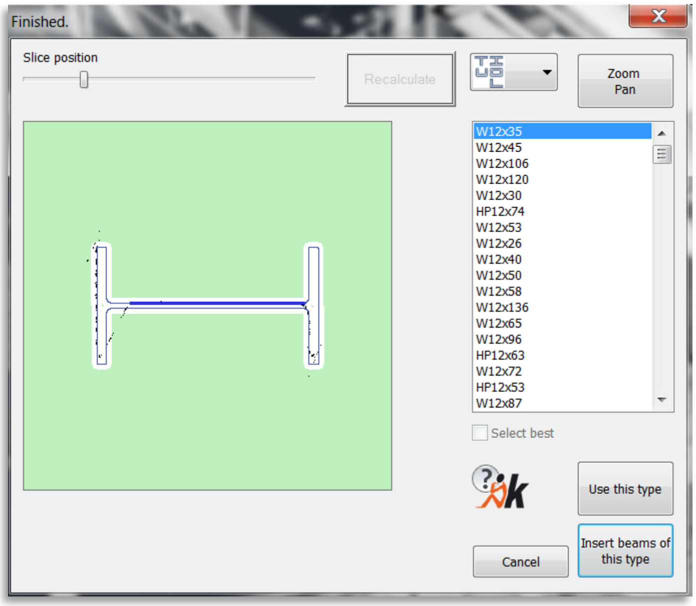


Figure 18: Extraction algorithms tied to standard catalog

Matching Design Constraints:

As discussed in piping design, structural members must also undergo the process of applying constraints if the user intends to bring detection objects into intelligent design packages (Advanced Steel, Autodesk Revit, Plant 3D, etc.). Centerline grids must align properly to avoid misconnections in final design software.

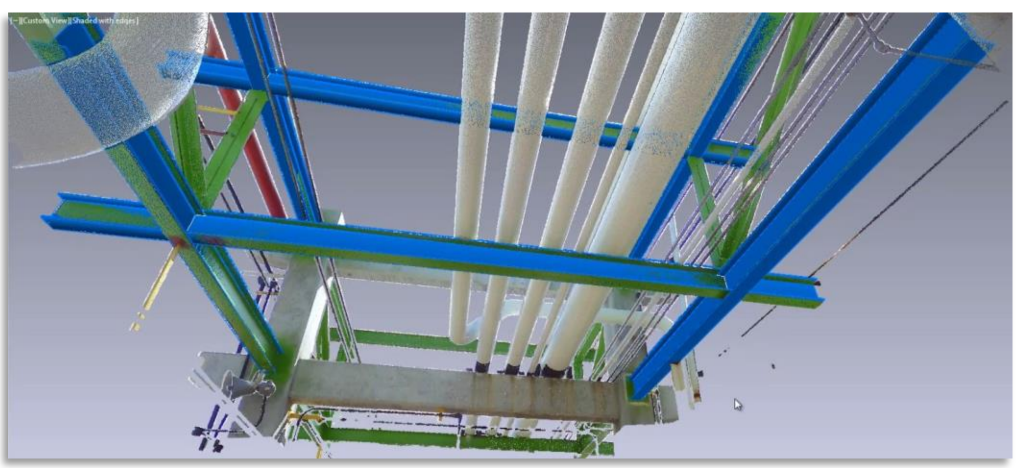


Figure 19: Beam centerline grids must align.

Interference, Clash detection

Verifying and testing for interference between existing field conditions and new proposed design has never been more efficient. In this case, a clash detection tool is extremely valuable. Fortunately, Autodesk provides this functionality directly in Autodesk Navisworks Manage software.

Navisworks and Navisworks Manage

Please read the recommended instructions below for clashing between model point cloud with Manage.

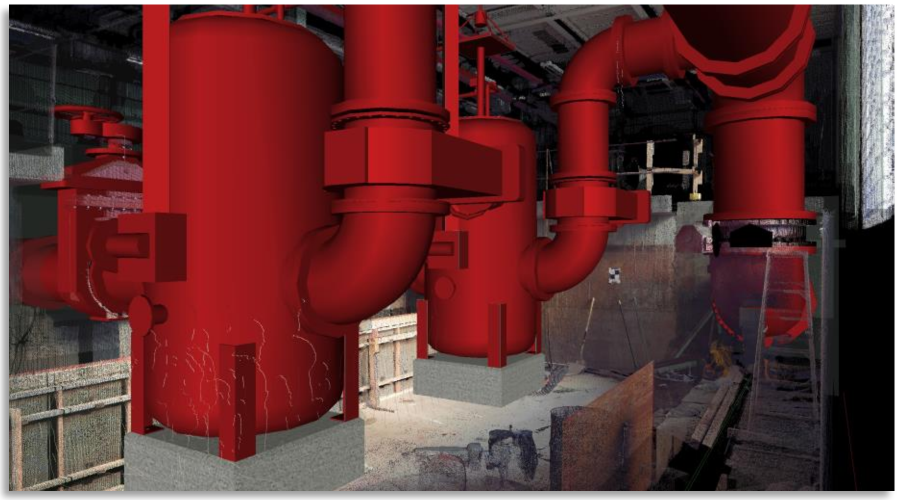


Figure 20: Ready for clash check between model and cloud

Workflow options:

1. APPEND a DWG to Navisworks which includes the finished drawing objects. The user may remove the point cloud from the DWG before appending.
2. Append the RCP or RCS point cloud file in Navisworks 2014
3. If needed, scale the point cloud object to match the units of the DWG objects by selecting the “reality capture” cloud, right clicking and choosing “units…”
4. Click the CLASH DETECTIVE icon in Navisworks Manage which opens up two columns
5. On the left column, choose the point cloud data referenced in the DWG. Make sure that
6. the clash setting is marked for POINTS.
7. On the right column, choose the solids/surfaces referenced in the DWG. Make sure that
8. the clash setting in the column is marked for SURFACES
9. Set an appropriate tolerance for the clash searching between points and solids
10. Set the clash type to CLEARANCE and Run the clash detective
11. Visualize the clashes detected in Navisworks. You will notice the highlighted solids/surfaces which clash with the point cloud data within the desired tolerance set.

As an alternative to automated clash detection, which may yield more results than desired (and is only available in the Manage version of Navisworks), users may also perform a simple visual inspection. Navisworks allows users to navigate to the inner diameter of pipe runs. By simply walking through the pipe run model, users may look for point cloud data which appears inside of the solid pipe. This can indicate a clash between existing conditions and proposed model.

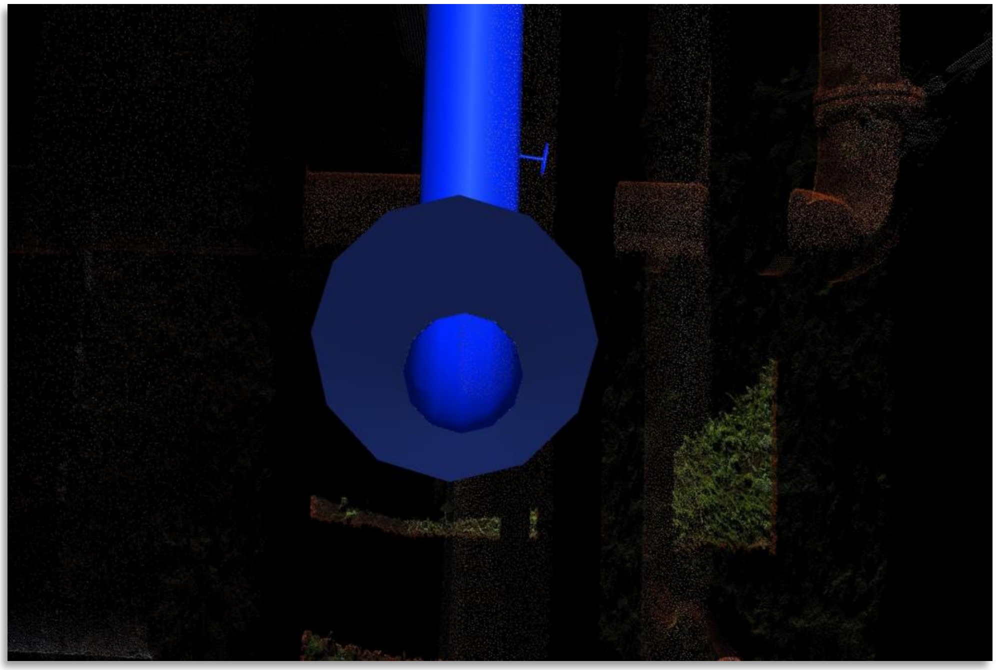


Figure 21: Walking through pipe run may reveal clashing points