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CIGRE US National Committee
2022 Grid of the Future Symposium

Integrated 3D Scanning Methodologies for improvements in Asset Upgrades

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SUMMARY

3D laser scanning tools have been piloted at a National Grid HVDC facility to create 3D technology maps to assist with operations and maintenance performance. Using the Trimble X7 3D Laser Scanner and RealWorks software, point cloud coordinate data is captured and compiled to generate a geo-spatial 3D map of facility areas and equipment. [1] The station trialed the Trimble system to investigate two major equipment upgrades, aiming to provide baseline dimensions, geo-spatial references, multiple scanning points, measurement precision verification, and switching, all while improving site and worker safety. Additional investigation was made into integrating the payload with mobile robotic technology, providing added benefits in terms of mobility, routine mission capability, and added cost savings. This paper will detail the National Grid station's two use cases: an HVDC transformer installation and HVAC upgrade project, which were used to test the laser scanning's functionality and potential. Although the data rendered from the 3D scan was consistent with spatial arrangement functionality, flawed results suggest the need for more refined camera and laser-based technology. Despite this, the potential benefits from having a completely functional system are extensive. Examples of such benefits will be illustrated from the case studies, including details of how the 3D scanning tools were able to verify the accuracy of transformer bushing and valve hall dimensions, verify and compare documentation information, and provide cost benefits from a management perspective. With a growing number of facilities in the power system maintain aging equipment, many short and long-term upgrades are required to sustain reliable operation. [2] As sites plan to decide either brownfield or greenfield options, there is a gap to address short term upgrades to keep sites operationally available. Another benefit realized was the minimization of worker hazards, with the mobile robot and scanning system often replacing the need for a human worker entirely. This provides an extra layer of safety for personnel, and with the catastrophic failure potential from end-of-life equipment, having the ability to remotely operate, review, and store data can prove essential. Thus, this paper will additionally investigate traditional scanning methods, and compare their accuracy, precision, and cost-saving benefits to the integrated and portable scanning system used at the station. As the pilot for the Trimble system is reaching its end, cost-benefit analysis has justified the potential purchase of a scanning system, and multiple product options are being explored. The station is also considering an automated approach to scanning by utilizing the pre-programmable routine capability of the attached mobile robot. Having consistent and up-to-date data that can then be

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converted to various compatible 3D model formats would prove greatly beneficial. Combined with data storage on a cloud-based or subscription-based data archive, engineers at the station would all have easy access to models, geo-navigation data, and digital twin capabilities in future use cases. To conclude, the paper offers recommendations for system enhancements based on post-analytics, proposing future upgrades to integrate with existing SCADA tools and data platforms to create a cohesive, unified system.

KEYWORDS

LiDAR, 3D Laser Scanning, Trimble, Robotics, Point Cloud Analysis, Geospatial Modelling, Transmission Power Systems

INTRODUCTION

At a National Grid HVDC station, the use of advanced geospatial scanning technology is being tested for implementation in various operations and maintenance applications. Laser Imaging, Detection, and Ranging (LiDAR) tools can be used to generate 3D technology maps through automated point-cloud technology, providing rapid, highly accurate digital models of the system's surroundings. [3] For implementation at the station, a Trimble X7 3D laser scanning system was tested to assist with two equipment upgrade projects that required baseline dimensions and precision verification of an energized system. Performing these studies revealed significant areas for improvement, however, results proved how 3D laser scanning can provide invaluable data in a variety of use cases at the station. The team continues to investigate the laser scanner's potential, considering integration with cloud-based data archiving, digital twin capabilities, and enhanced usage using mobile robot technology. This paper will detail National Grid's experience piloting the laser scanning technology by providing an overview of its use cases, observations and feedback generated from the tests, and recommendations for integration into existing SCADA analysis tools.

USE CASES

In pursuit of continuous improvement, National Grid has been seeking ways to enhance its performance with the use of smart technologies throughout its business. In May 2021, a mobile and versatile robot dubbed "Spot" joined the station's team. Spot was designed to integrate with various modular payloads to provide an extensive set of capabilities, including

Figure 1: *Images of the robot with the attached Trimble X7 payload while scanning the area of the converter transformer.*

infrared imaging, radiation detection, and noise anomaly identification. [1] One of such custom attachments is the Trimble X7 3D laser scanner, which uses its technology to scan and capture precise geospatial data of its surroundings. [2] This data, compiled with point cloud processing and analysis, can then be viewed in 3D format providing users with real-time, highly accurate dimensional information. [3] Having already observed the success of the Spot robot in a variety of situations at the station, the National Grid facility chose to explore the use of the Trimble

LiDAR attachment in two impending maintenance projects. The first project in which Spot would be employed to assist was the installation of a spare HVDC transformer into service. The station saw the opportunity for the laser scanning technology to provide precise measurements of the transformer to be installed, which could then be utilized in the verification of baseline dimensions and in the preparation of the transformer's move to the installation site. Thus, in July of 2021, engineers at the station sent Spot into the station yard to scan and generate a 3D model of the new transformer. Using a handheld controller, the station engineers remotely directed Spot to circumnavigate the area of the transformer while the laser scanner continuously captured 3D data of its surroundings. With the point-cloud processing used by the Trimble scanner, each collected data point corresponded to an x-, y-, and z-axis coordinate from the scanned area, which was sent back to engineers in real-time. [4] After receiving the data points, the Trimble RealWorks software then compiled the information to generate a 3D model of the area, shown in Figure 2. From this, engineers were able to zoom and navigate through the model, perform highly accurate measurements, and view even the most intricate hardware safely and efficiently. The entire scan took only 45 minutes to complete, with the engineering team then only needing an additional 25 minutes for review. With the Spot and Trimble combination providing such promising results, the facility decided to further test the laser scanning capability in a second project.

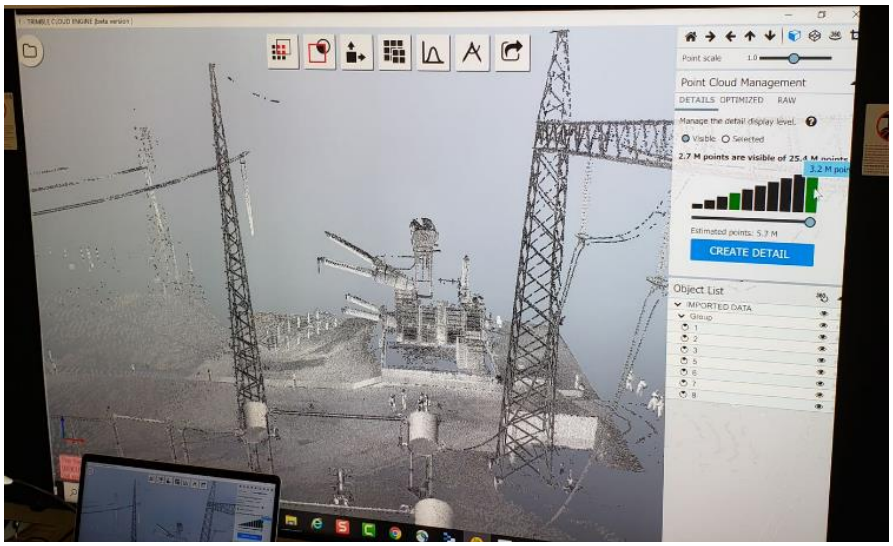

Figure 2: *An image showing the 3D model being generated as the Spot robot traversed the transformer location.*

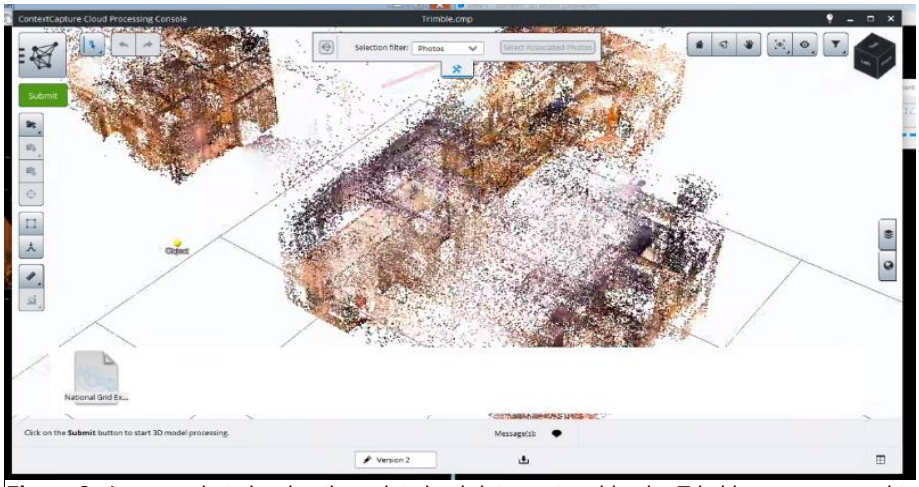

Figure 3: *A screenshot showing the point cloud data captured by the Trimble scanner, used to generate the 3D model of the HVAC system.*

In the fall of 2021, the National Grid station began a project to upgrade the HVAC system throughout their facility. To proceed, the layout and measurements of the entire system were required, including the smallest pieces of equipment in the hardest-to-reach locations. The station identified this as an excellent opportunity to test the LiDAR system, hoping to use its data to accurately measure the system's dimensions and verify outdated layout documentation. For this study, the facility chose to test the Trimble scanner on both a stationary tripod and on the mobile Spot robot. Though both setups resulted in comparable data, the versatility of Spot proved to be the most useful and was thusly utilized. In Figures 3 and 4, the point cloud data from the HVAC's scan can be seen. HVAC building required major upgrades in terms of conduits, ducts and other equipment upgrades where getting 3D data could provide vital technical and cost benefits to the front-end cost of the project.

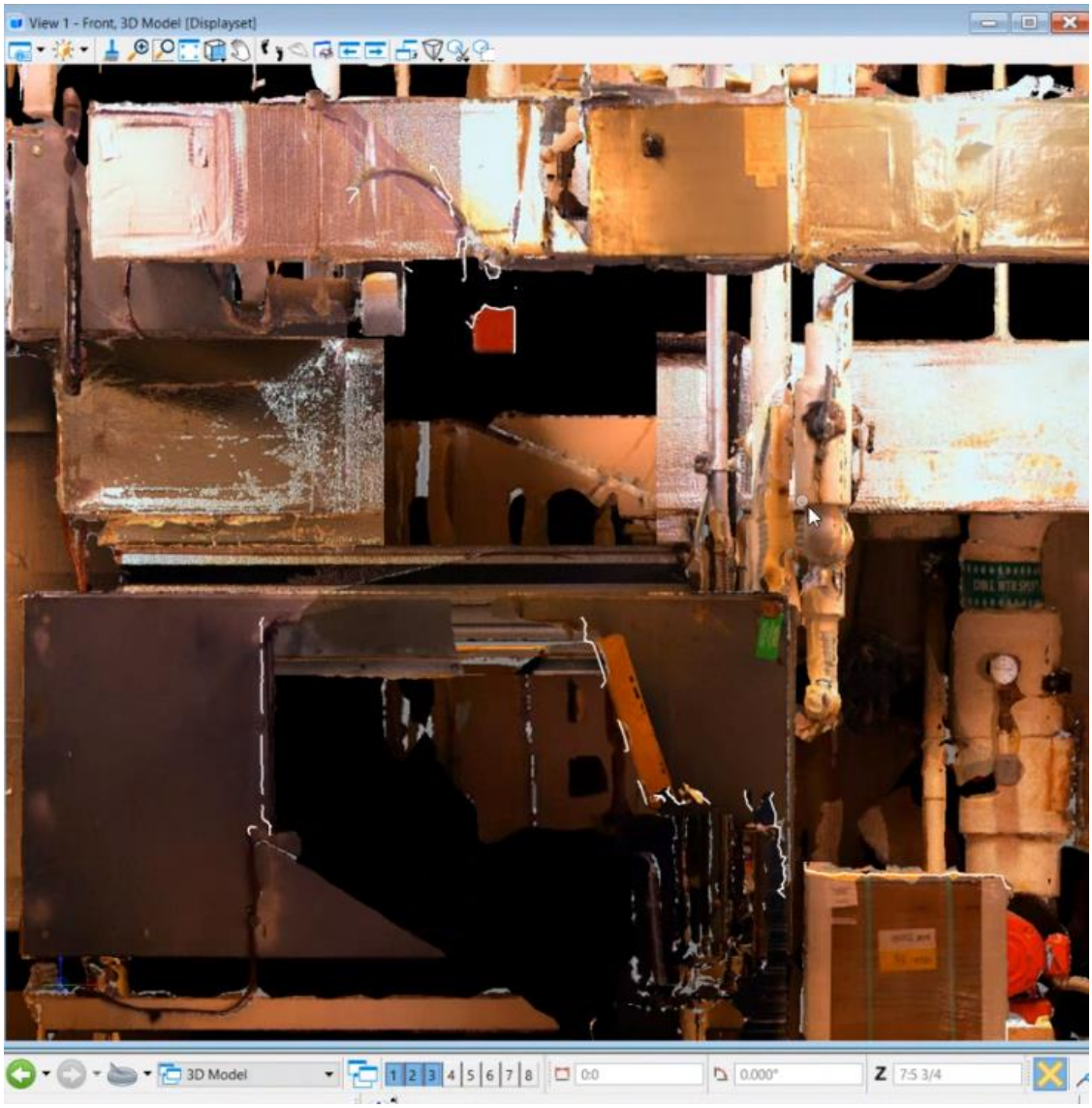

Figure 4: *A screen capture of the RealWorks software presenting the 3D model of the HVAC system, with photographs overlayed onto the data.*

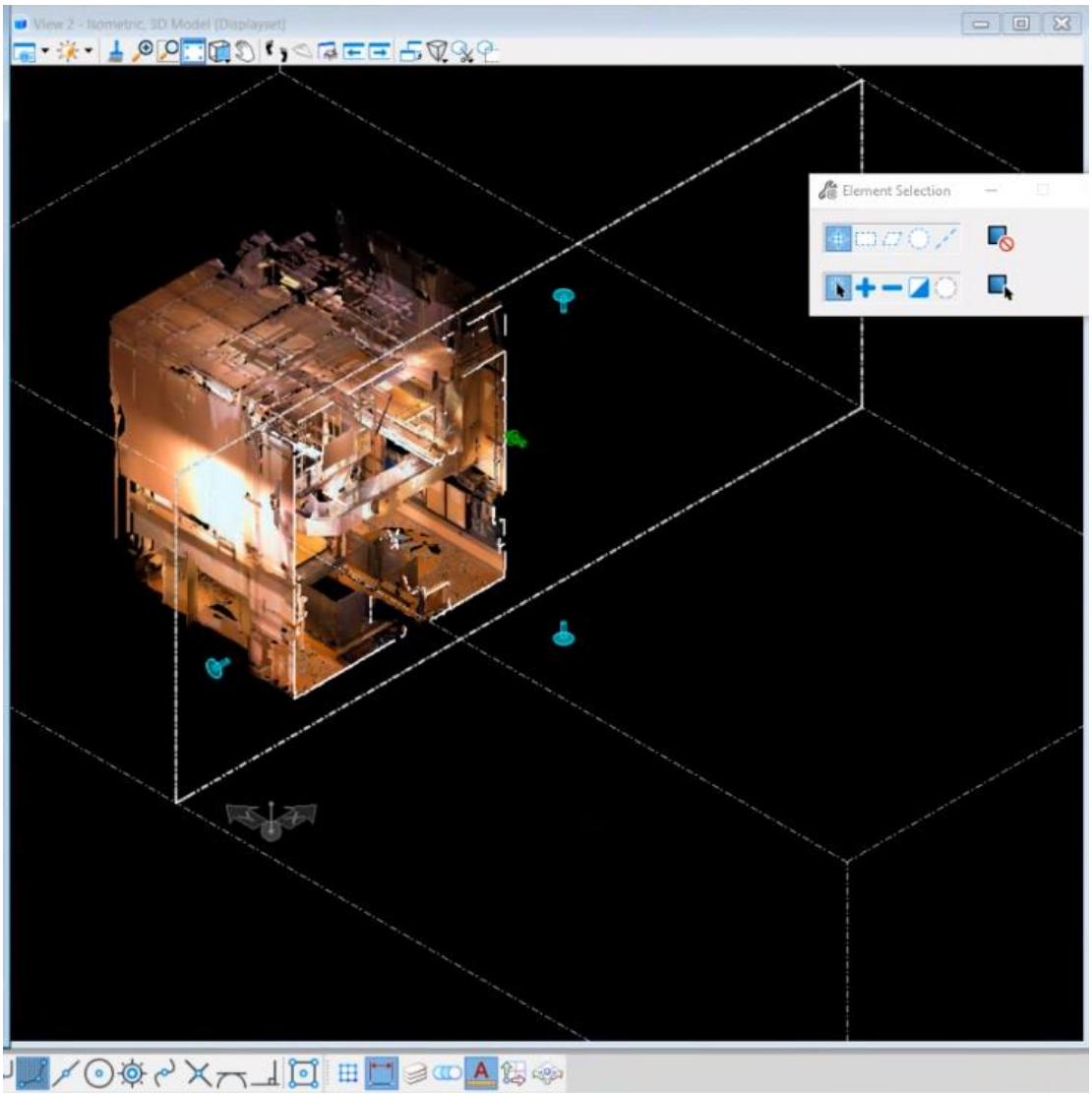

***Figure 5**: A screen capture of the RealWorks software showing an overview of the 3D model of the station HVAC system.*

The RealWorks software enabled the creation of the 3D model, which then overlayed photographic images onto the data for enhanced visual perception (Figure 4). With the model, engineers were then able to view any desired part of the HVAC system and measure point-to-point dimensions. In addition to gathering new measurement data, the precision from the 3D model allowed engineers to cross-check ageing documentation and correct unrecorded changes that had been made since the system's installation. This use case was similarly fast, with the scan taking only 30 minutes per room to complete, and engineers spending only 25 minutes to retrieve the needed data. Thus, with the two use cases complete, the station examined their experiences utilizing the 3D laser scanning system and analyzed the results.

COMPARATIVE ANALYSIS:

In one of our recent projects to perform measurements on X and Y windings of HVDC transformer, using an alternative technique of ground based lidar detection shown in Figure 6, shows the terrain navigation and conventional Lidar techniques. This requires the placement of Lidar sensors and scanning from multiple locations to obtain exact set points to create Lidar data. In this case it involved 1+ days of setup, installation, and engineering time to create Lidar data and perform readings. Our analysis showed the Trimble based data collection and comparative analysis provided 2mm accuracy results which resulted in better design of valve hall frames for the X and Y windings which could potentially results in thousands of dollars of cost savings. The demonstration of Trimble results is compared in Appendix Figures 7 through 10.

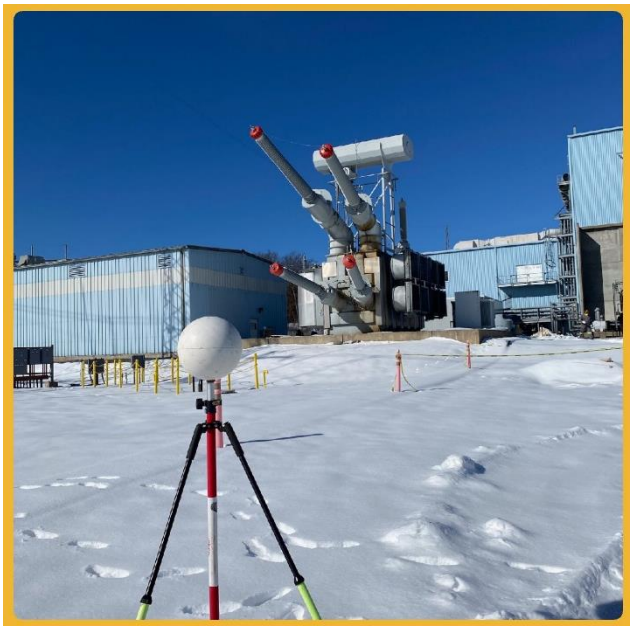

***Figure 6**: Lidar scanning of HVDC transformer using alternative techniques*

CONCLUSION

With the advent of multiple brownfield and greenfield projects, advanced planning of 3D models can be used in the scoping of projects and provide savings in design and documentation costs along with any savings to the installation costs from the front-end of the project delivery and installation. With the exploration of multiple scanning technology from aerial to ground based systems, Trimble payload with existing robot integration has scaled the capability from mobility and data collection by providing time savings and cost savings along with accurate and powerful results with e57 and CAD formats for design analysis. The final results impact the overall condition of the asset and suggested improvements in asset maintenance.

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APPENDIX

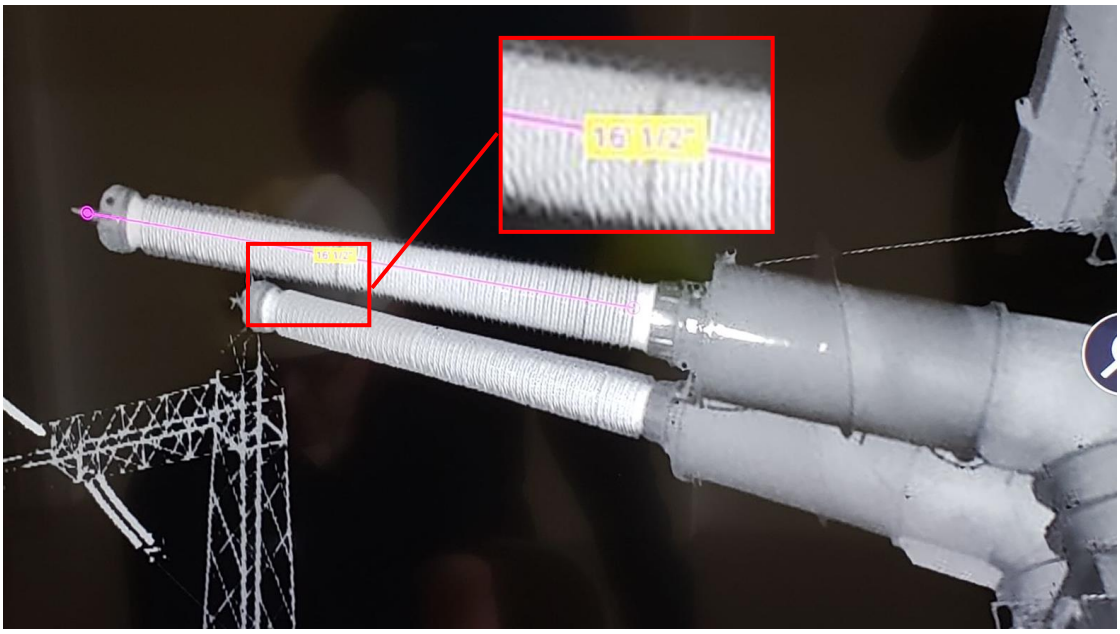

Figure 7: *Image showing the real-time measurement of a transformer bushing based on the 3D laser scan data.*

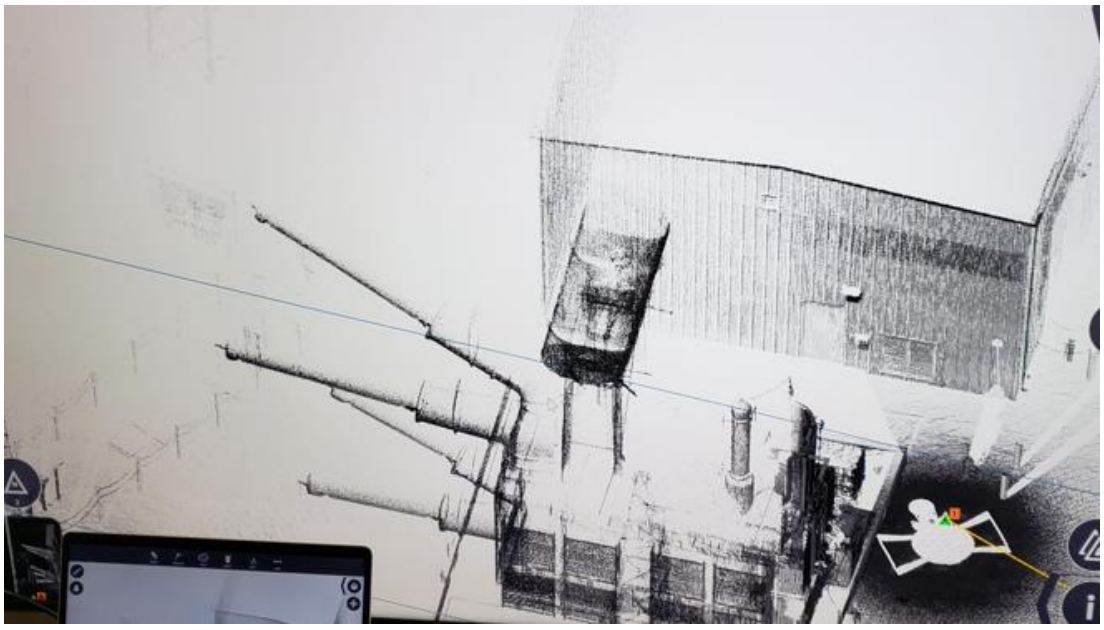

Figure 8*: A picture showing the transformer's point cloud geospatial data modelled in the RealWorks software.*

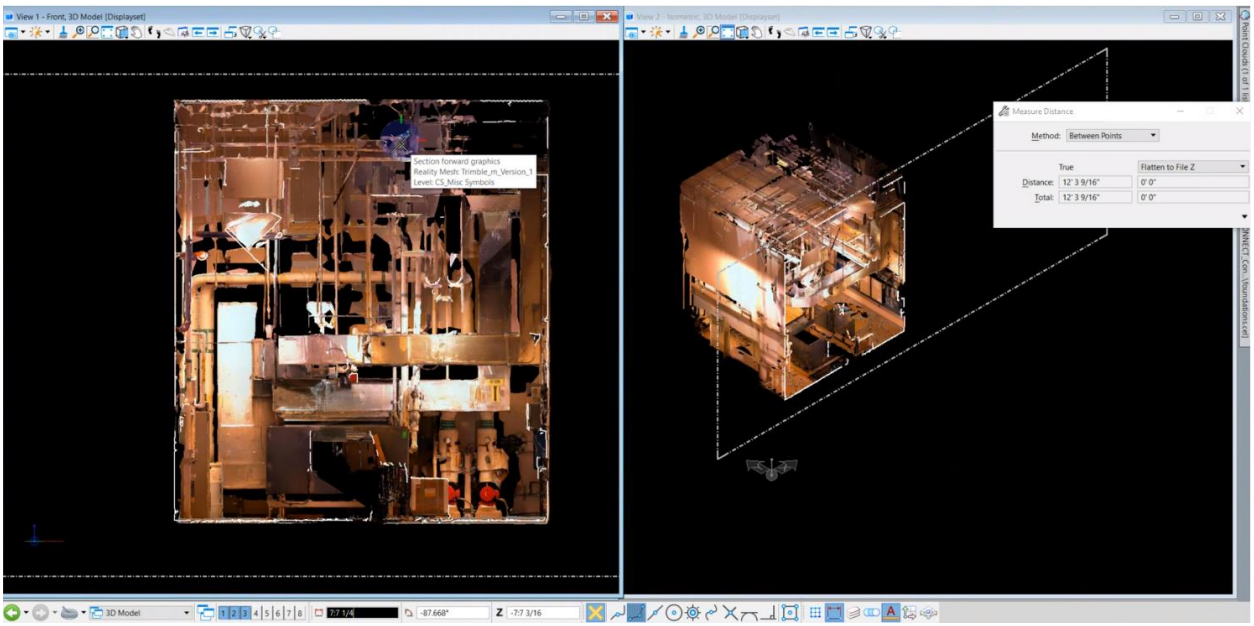

Figure 9: *A screen capture of the RealWorks program displaying the HVAC system's 3D model, and providing a measurement based on two user-selected points*

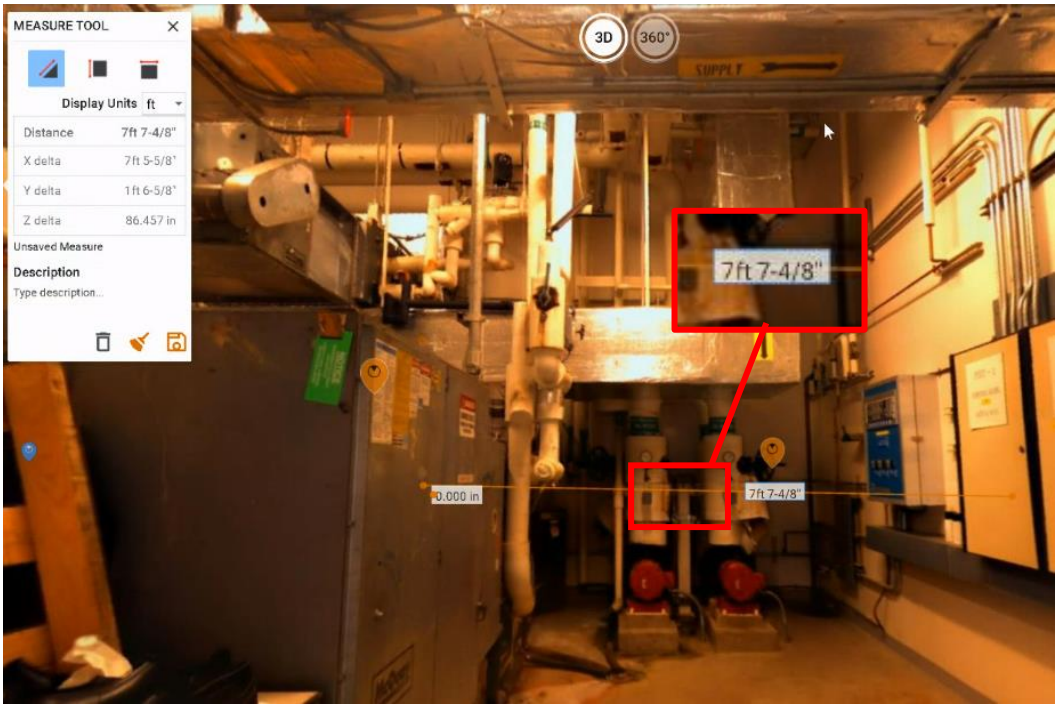

Figure 10: *A screen capture of the Trimble 3D model software, illustrating the point-to-point dimensional measurement capabilities.*