3D Laser Scanning: Benefits and Paybacks for Industrial Plant Design, Construction and Operation

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Executive Summary

This paper summarizes the economic benefits of applying 3D laser scanning technologies to the design, construction and operation of industrial plants. We examine how these technologies deliver four main benefits: risk mitigation; cost reduction and schedule compression; improved safety for capital project delivery, maintenance and operations; and how these benefits are realized and exploited by asset owner/ operators, engineering/construction firms and 3D laser scanning service provider contractors. This paper was commissioned by Faro Technologies, Inc., a leading supplier of 3D laser scanning solutions.

Key Findings

Risk mitigation: All industries experience rogue projects where cost, schedule or safety has spiraled out of control due to incomplete or incorrect as-built documentation or inadequate dimensional control procedures. Laser scanning workflows have proven beneficial for reducing project risk on brownfield projects, particularly where energy densities are high; site access is difficult or expensive; modular design and fabrication methods are deployed; and project schedules include acute sensitivities.

Cost and schedule reduction: Laser scanning has reduced total installed cost for brownfield projects by 5-7% and has reduced contingencies for rework to less than 2% compared to traditional survey methods. These results are remarkable not only for the magnitude but for their consistency across a wide variety of projects. Achievement of these cost savings sometimes requires higher initial investment in 3D data capture solutions than traditional methods (total station, piano wire, spirit level, plumb bob and tape measure). Schedule compression of as much as 10% has been reported when 3D laser scanning has been deployed. Such savings dwarf the cost of data capture and modeling in applications such as nuclear power generation where outage time costs $1 million/day and offshore platform revamp production values can exceed $500,000 per day.

Safety and regulatory compliance: Owners are subject to increasing governmental scrutiny and regulation which demand the creation and upkeep of not only the as-built but as-maintained condition of production assets. Laser scanning is increasingly used to comply with health, safety and environmental imperatives. Compared to manual data capture methods, laser scanning methods are often safer. The remote sensing ability of today's scanning systems and their rapid data capture means reduced jobsite exposure. Offsite fabrication methods, safer where hot work permits are required, can be used with confidence when adequate dimensional control ensures bolt-up installation instead of onsite welding.

Improved quality and other benefits: Complete and accurate dimensional documentation based on laser scanning has resulted in myriad collateral benefits ranging from the ability to perform better simulation of asset and equipment performance for training purposes, better visualization to coordinate multiple engineering disciplines and craft construction, better visualization to secure project funding, more analytic and quantifiable construction monitoring, and more flexibility to accommodate scope change.

Risk Mitigation of Capital Project Execution

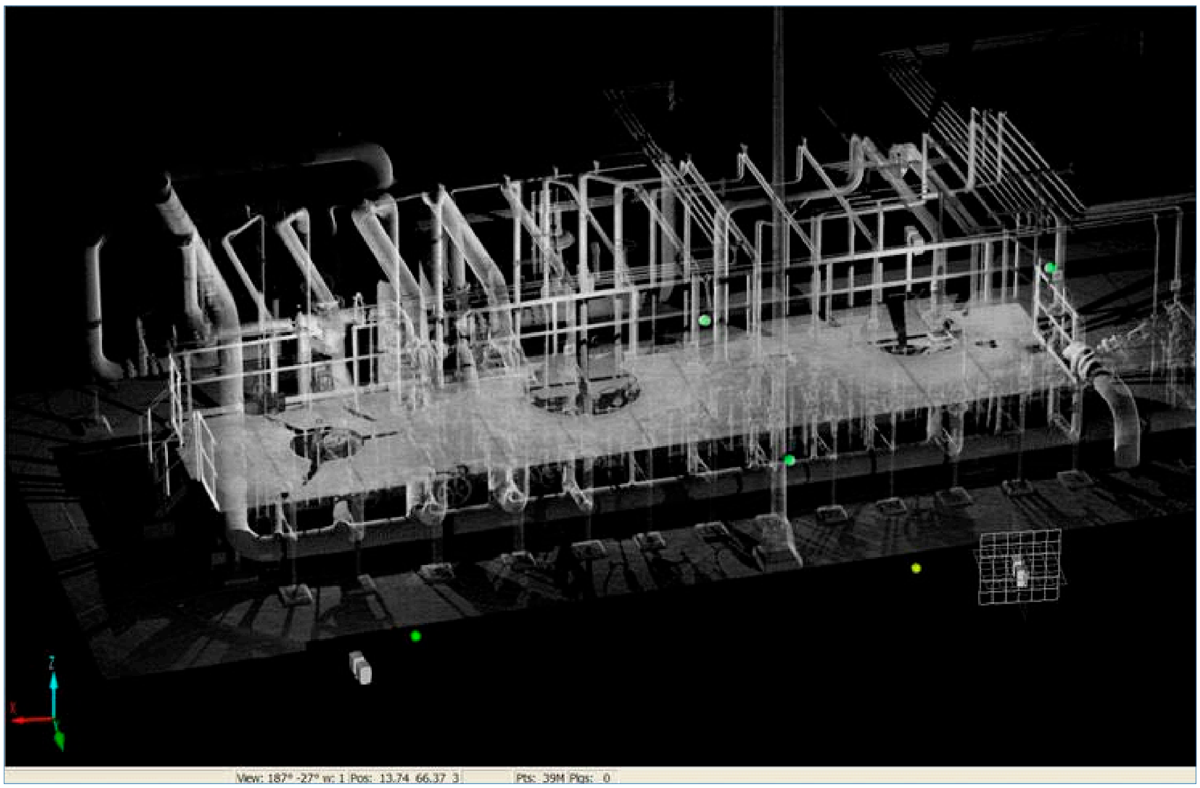
Mitigation of project risk is at the heart of successful project management. Laser scanning is a proven tool for containing and reducing risk for not only brownfield or revamp projects but also projects deploying modular construction methods and projects where schedule sensitivity is acute. Both the high level of detail and accuracy delivered by 3D scanning solutions allow project teams to:

- Reduce time and errors by:
    1. reducing the number and types of consequences from manual measurement errors, damages, injuries and outages;
    2. reducing time onsite for inspection;
    3. providing advanced interference and clash detection for new installations without the need for return site trips;
    4. executing construction activities with fewer mismatches and design errors;
    5. coordinating efficient scaffolding in complex plant environments during shutdowns;
    6. responding to schedule upsets and changed field conditions with more flexibility;

- Improve planning and design by:
    1. improving overall plant processes by creating drawings and models where none previously existed;
    2. analyzing engineering design plans, checking for clashes between existing conditions and new design elements and evaluating alternatives before project costs are committed;
    3. designing closer to acceptable factors of safety, and communicating design intent efficiently and accurately;

- Improve work processes by:
    1. providing consistent as-built documentation for CAD/design specifications for plant layout;
    2. updating documentation in piping and instrumentation diagrams (P&IDs);
    3. evaluating pipe runs for various regulatory compliance requirements;
    4. providing exact measurements for demolition and removal of plant components in existing facilities;
    5. prefabricating components with little to no excess material or incomplete welds;
    6. visualizing construction plans prior to execution;

7. visualizing as-is conditions for asset management, inspection, constructability and funding procurement efforts;
8. accelerating construction, decommissioning and modification processes;
9. accommodating scope changes more intelligently;
10. attracting new design and copnstruction talent who have been educated in the use of 3D



Piping isometric model (courtesy of Faro Technologies)

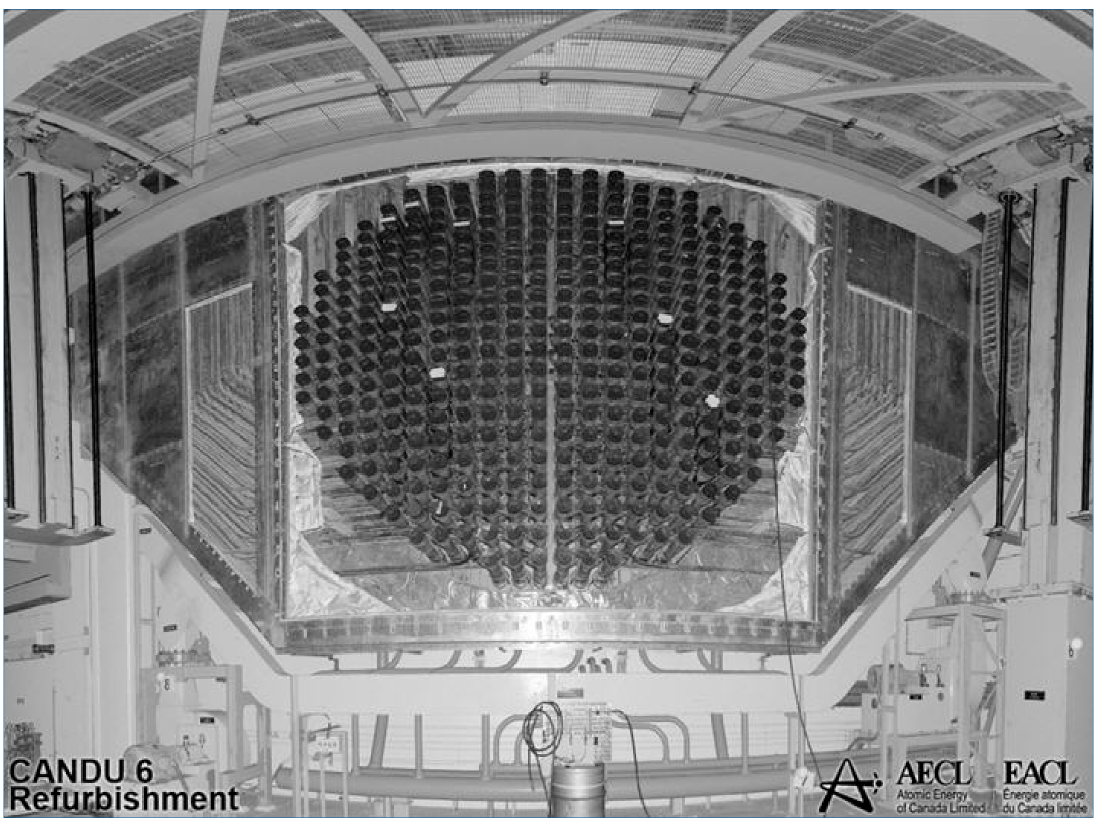
Aaron Smith, tracker manager at Plymouth, Mich.-based Variation Reduction Solutions, Inc. (VRSI), a FARO LS880 user for large volume scanning, notes that clash detection in plants is critical to successful projects. “If you find any fractures that are possible inside a system [prior to project start], it cuts down enormous amounts of time and money. If a crew comes in to put in a condenser and they realize there is a lot of piping in the way that nobody thought of, the crew isn’t being utilized for the time they’re allotted—there’s a lot of lost money and time. And a lot of petrochemical and nuclear plants have very tight time schedules—they need to get up and running or they’ll lose money. When companies start figuring out the amount of time they’ve spent in the field [with laser scanning] compared to how many return trips they’d have to take without laser scanning… the cost savings of laser scanning investment is enormous. Scanning eliminates [numerous return trips] because you already have [the data] in a CAD model. You can have a guy or two preplanning a mission instead of sending an entire crew of people that have to sit there for hours out of the day, which would cost hundreds of thousands of dollars—not including the high cost of equipment rentals.”

Cost and Schedule Savings

Work flows based on 3D scanning solutions reduce costs for the industrial plant market in three main ways. First, asset owner/operators benefit from reduced outage and shortened construction schedules for revamp, modification and upgrade projects. Second, laser scanning can reduce total installed cost for brownfield projects by 5-7% and has reduced contingencies for rework to less than 2% compared to traditional survey methods. Finally, in many instances, laser scanning-based field data capture is less expensive compared to traditional methods based on manual measurement using measuring tapes, plumb bobs, spirit levels and piano wire.

Reduced outage and shortened schedule time

Limiting outage times and shortening construction schedules are top priorities when lost production is expensive or capital costs are high. Nuclear power operators may have to purchase electricity on the spot market to replace production lost to unscheduled or delayed outages; power replacement costs can be on the order of $1 million per day. In these instances, the potential for lost operating margins due to project delays dwarfs 3D data capture and processing costs.



CANDU 6 Reactor face at Point Lepreau Generating Station scanned with a FARO LS880 scanner.
Note that each pixel has an (x,y,z) coordinate. Image courtesy Atomic Energy of Canada.

Similarly, lost production time on offshore construction, refinery and petrochemical projects where the price per cubic meter and energy densities are high can cost hundreds of thousands of dollars per day. Accounting for deferred production varies by industry, but unproduced oil remains on the balance sheet as proven reserves. Opportunity cost calculations are subtle in these instances and beyond the scope of this paper. But lost production is lost revenue. In these instances, investing several thousand dollars per day to scan and model the as-found condition of the facility to create accurate 3D information is a bargain.

> Mark Carney, technical lead, laser scanning, Atomic Energy of Canada Limited (AECL), a leading nuclear technology and services company, who is currently using FARO laser scanning solutions for refurbishing/retubing older reactors, says having up-to-date as-built information lets engineers know "what pressure vessels need to be refurbished, know their exact locations and what they're surrounded by (and what the sizes of those surrounding components are), and know what precautions and what additional objects (brackets), etc., might be needed to replace and refurbish parts. It helps with future design planning… Knowing you have an opening that's 60" on a drawing but having scan data show that the concrete poured opening is 58" and knowing that a $4 million piece of equipment has to fit in that opening … is huge!"

> VRSI's Smith says that "sometimes workers will think one area of piping needs to be cut out yet realize later that it never needed to get cut out. They then have to cut out another area instead. So, they lost time beforehand and then they lost time during the project because they need to stop, get everything in a safe position, then start cutting again." He adds that these setbacks also dip into a plant's operations schedules and levels of mandated cleanliness, as well as introduces additional risk of explosion from high levels of oxygen or radiation dose.

Driving rework contingencies to below 2%

Project managers from a wide variety of industries report that having complete and accurate 3D as-built information based on 3D scanning has meant reduction of rework on brownfield projects to below 2%--and often below 1% of total installed cost.

These savings are achieved in part by reducing design errors. With today's 3D scanning and modeling tools, and leading plant design solutions, clashes between the as-found conditions of the plant and the new design can be trapped and resolved before construction. Typically, it is much less expensive to re-route piping on a computer screen than to cut and weld new spools in the field.

> Mike Gunn, president, 3Space, Inc., Indialantic, Fla., a service provider since 1988 and laser scanner user since 2000, says, "New methods allow for correct load path so halfway through the building, your components don't get stuck. Potential pinch points are identified and rectified in advance of the outage or early in the outage before the parts are actually moving in." This, he says, can result in savings of a half-shift, and that many plants finish scan work during outages in four or five fewer days than planned, thereby saving about a million dollars per day.

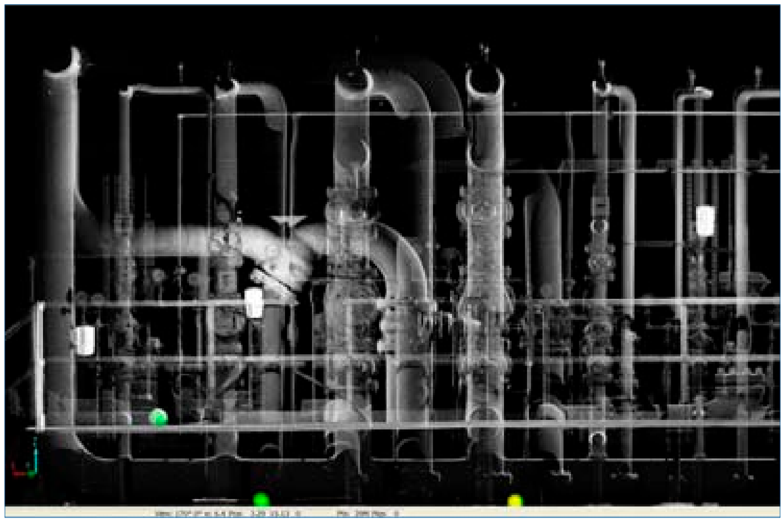
Other savings result from better construction sequencing and coordination. Removal of large vessels and heavy equipment can be simulated and then optimized, tasks that demand complete and accurate 3D information in order to have confidence in the result. Demolition of existing piping, steel and concrete structures can be more surgical with these methods. Starting with accurate geometry allows drawings, designs, piping isometrics, code requirements and various standards to be integrated, which allows for better communication between and among engineers and other disciplines. Reliable as-built data documentation also reduces, speeds up or sometimes eliminates training certification requirements necessary for plant work.

> Paul Ronaldson with James Fisher Inspection and Measurement Services (JFIM), a subsidiary of James Fisher and Sons, Deeside, UK, says single-point uncertainties of 2-3 millimeters offered by FARO 3D scanning systems are more than sufficient for most decommissioning projects. "The data collected by laser scanning is much more complete and quantitative than with video surveys," he says. "Precise mechanical models can be constructed and the data can be re-inspected for additional information (that may have been outside of the original scope) without the need for re-entry into the harsh environment. For example, by importing CAD models into the point cloud data, a simple laser survey can later be used to determine whether or not additional equipment can be introduced into the area without clashing with existing equipment."

Optimized modular construction – greenfield applications

The value of 3D laser scanning-based workflows is not confined to brownfield projects. Cost and schedule savings for greenfield projects based on modular construction methods have also been realized. Modular construction methods, which allow constructors to fabricate spools, skids and pre-assembled modules offsite, are sometimes the only way to execute projects in environments where conditions are extremely harsh or remote like the high Arctic, for example. Modular construction has also been deployed in tight labor markets, shifting work to markets where fabrication costs are lower.

Successful modular construction demands dimensional control; components, equipment, spools have to fit when they show up on the jobsite. That sounds simple but it isn't—the dimensions of fabricated items don't always correspond to the design specifications. Human errors, misunderstandings, equipment substitution and poor communication can all lead to rework on the construction site. Onsite solutions to fit-up problems aren't always subtle: cutting torches, welding units, jackhammers, hydraulic jacks and come-alongs may be the field choices. Maintenance experts say that components stressed at installation time by these methods often wear out more quickly, often unpredictably—a cost burden which is visited on asset owners.



A close-up capture of a piping section.

Left unmanaged, the cost and schedule impact of fixing fit-up problems in the field can eat up the savings of partitioning the work in the first place. Laser scanning these items and performing a digital fit-up before they are shipped to the construction site has prevented costly field modifications on these projects.

Impact on bidding process

The increased availability of accurate as-built 3D geometry based on laser scanning suppresses owner appetites both for contingencies in the contract documents and for change orders once a project has commenced. The business tactic of winning a contract with a low-ball bid with the expectation that the profits will be made up on the change orders is less attractive in a bidding environment where the as-built documentation is both accurate and complete. Engineering/construction firms that have mastered 3D scanning work flows appear to have a significant competitive advantage. Winning bidders without rigorous dimensional control procedures may well be exposed to stiff losses. Indeed, some engineering/construction firms report that they use 3D scanning on most revamp projects.

Lower cost for data capture

Our research does not indicate that 3D laser scanning costs less than traditional data collection/survey methods in every instance. However, there are many industrial plant applications where scanning does provide cost advantages over conventional methods. The expense of data collection on remote or difficult-to-reach sites properly includes travel overhead. Both the number and the duration of these field visits can often be reduced because of the completeness and accuracy of a 3D scanned site inspection and field verification. The case for scanning is even more compelling for offshore platform work where travel and lodging costs are extremely high.

Safety and Regulatory Compliance Benefits

Industrial plant environments are often complex and dangerous environments. The first rule of safety is to limit the time humans are exposed to these dangers. The speed of today's 3D scanning devices plus the inherent remote sensing capabilities mean that data capture using these instruments can be safer than traditional industrial survey methods. Alternatives, such as clambering over a pipe rack with a tape measure to capture a tie-in or erecting scaffolding to get access to hard-to-reach plant areas, can either be downright dangerous, expensive or time-consuming, or all of the above. As VRSI's Smith states, "Safety is planning beforehand."

On July 6, 1988, the Piper Alpha oil production platform in the North Sea exploded and 167 workers perished. Following this horrific incident, the oil and gas industry looked for new ways to reduce the requirement for field work under hot conditions. Dimensional control was seen as a way to reduce the requirements for hazardous field operations such as cutting and welding of pipe spools. While much dimensional control work is executed using total station-based measurement, increasingly, laser scanning is used to survey offshore platforms for revamp purposes.

In cases where offshore platforms have been damaged by extreme weather conditions—Hurricanes Ivan and Katrina in the Gulf of Mexico, for example—laser scanning has been used effectively for damage assessment. Following Hurricane Ivan in 2005, Chevron Corporation contracted a laser scanning survey of the damaged Petronius platform, citing safety as one of the key drivers. Laser scanning offers high value for assessing damaged areas that are potentially hazardous because of stored mechanical energy. Using laser scanning, these areas can be assessed without direct physical access.

One of the industrial world's most regulated markets—nuclear power—is beginning to make extensive use of 3D laser scanning to address health, safety and environmental concerns. The nuclear power industry's "As-Low-As-Reasonably-Achievable" (ALARA) concept, a major component of several worldwide radiation protection programs, mandates the radiological goal of protecting each worker from high radiation dose rates.

> Ron Pride, a radiation protection specialist with a division of FirstEnergy Corporation, says 3D laser scanning from FARO scanners aids engineering, maintenance, radiological and operations work planning groups by allowing personnel to remotely view and evaluate areas in 3D where significant dose rates exist, slashing dose exposure. For example, personnel can identify exact locations and measurements of valve tags, either open or closed, without a physical walkdown. For owners of multiple plants, savings from laser scanning implementation are exponential when considering the reduction in work permits times the number of plants times hundreds of workers. JFIM's Ronaldson says that "By having (i) fast survey times and (ii) good survey information for planning subsequent operations, dose savings occur as a result of reductions in the time spent by engineering and operations personnel in high dose areas." Workers who do physically enter radiation areas with laser scanners are able to collect needed data at a rate of seven to ten times faster that of conventional methods. FirstEnergy's Pride claims a 20 percent decrease in millirems per hour with 3D laser scanning.

Mike Gunn, president, 3Space, Inc., reports that he insists on a baseline scan to determine the levels and types of radiation that will be absorbed during a particular scan job, thereby protecting workers even more and saving time.

AECL's Carney says the safety value of 3D laser scanning is immeasurable, as four or five surveyors can capture immense amounts of information in radiation "hotspots" and post them to a free Web-based viewer for use by 100 or so engineers. This negates safety training for a number of these engineers, a requirement that can take up to one week per engineer. Multiplying the savings from reduced training by the decrease in dose rates is considerable. Carney says in-reactor times usually total less than 100 hours per walkdown.

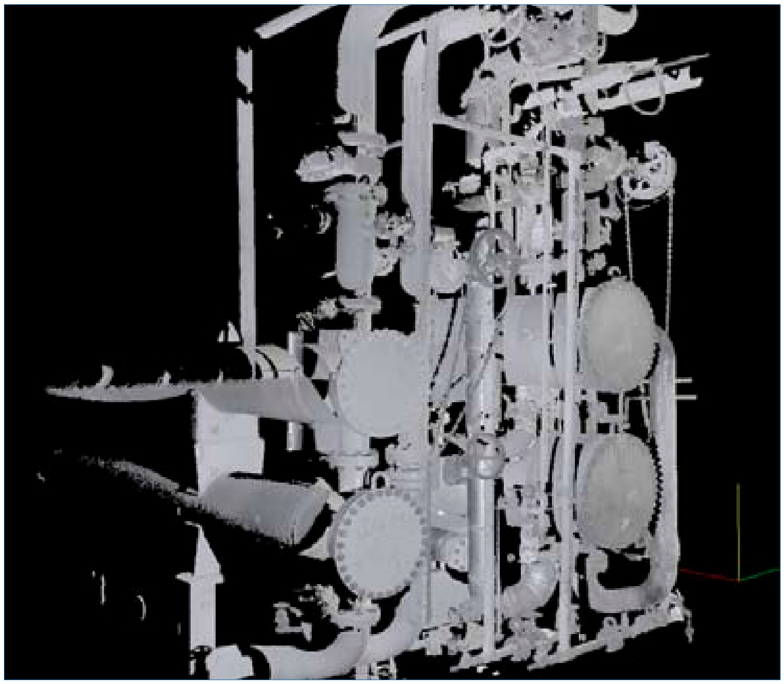
Industry can expect more oversight and anticipate more health, safety and environmental regulation going forward. Emergency response systems will have ever-increasing requirements for accurate 3D site data not only for planning purposes but also for delivering enhanced situational awareness to first responders. Achieving compliance will require better and more complete documentation of physical plant assets, and laser scanning is a proven technology for collecting this information.

Improved Quality and Other Benefits

Better as-builts yield better designs

The high resolution, completeness and accuracy of 3D scan data supports work flows that traditional survey methods can't. Traditional point-to-point surveys result in gaps between installed conditions and design conditions with undocumented changes. With scanned documentation, these gaps are filled with precise, photorealistic images and layered models of intelligent measurement data of piping components, HVAC, structural steel, electrical and other areas, allowing workers to perform automated interference and clash detection of proposed designs against existing conditions and verifying critical measurements and specifications of motors, pumps, breakers, valves, seals, etc.

3D data capture also shifts responsibility and attendant liability back to the designer, says Daryl Johnson, owner, Summit Engineering and Design in Washington State. Designers who use the technology can create more precise designs in fewer hours, thereby improving or omitting field fit-up and lessening the associated responsibility of the constructor and by providing clients with a higher-quality product.



Two registered scans viewed together of a set of heat exchangers and associated piping within a refinery. Image courtesy Summit Engineering and Design.

Enhanced collaboration among project stakeholders

3D simulations, animations and walk-throughs aid both technical and non-technical personnel. Engineers benefit from high-quality collision detection. Fabricators are armed with intelligence to avoid mis-fittings. Non-technical personnel, like government personnel, dignitaries and investment officers, are enabled to understand the value and capabilities of the technology in order to more confidently fund projects, project phases and potential project sites. CAD models merged with intelligent 3D data help health and safety personnel and others understand a facility layout in great detail, facilitate fewer walkdowns prior to a project and increase the awareness levels of team members regarding area surroundings. This is especially valuable to health physics personnel in nuclear plants, who can execute training without exposure to radiation. Graphical project status reporting is more accurate with 3D data and timelier than with manual methods.

> Intuitive digital infrastructure with a three-dimensional interface is increasingly becoming a part of the management practices of plant facilities, according to David Reinhart, vice president, INOVx. Management personnel, even at locations outside the facility—use these 3D data tools to manage assets from their desktops, work through inspection problems, get into maintenance and training processes, and plan efforts in emergency situations. "Having a digital infrastructure with a three-dimensional interface is so intuitive and so obvious," he says. "Imagine if you have a virtual world that you go inside of and see not only where things are, but with one touch, can find out everything

about that object or thing. If there's a problem, if there's an emergency, if there's a disaster, you can immediately re-create or find all the information about that thing to solve the problem in a very rapid way. And you can do it across your network—it wouldn't have to be at the facility. It could be working remotely from a special center." Reinhart says the demand for mega-sized projects is driving this intelligent network infrastructure."Initially, data capture was focused on dimension," he says."Now it's letting you do something with that data beyond the dimension. And if multiple disciplines and people throughout the enterprise can see it and work with it, and the system has the ability to stay up to date, the chances are that it's going to be used are great, and everyone benefits."

3D improves collaboration across several disciplines; project managers, engineering and design leads, fabrication, construction, operations and maintenance, installation and health personnel, and stakeholders at all levels have enhanced visibility into a capital project and corrected overlaps or downstream effects before they became costly. Engineers can request specific data from scanning technicians prior to them entering a site, thus receive more complete and accurate data in which to create workable designs and inspections. Fabricators are more confident during manufacturing processes and after delivering parts and components. Radiation health physics personnel conduct virtual walk-throughs of plants, and are able to monitor and establish efficient training for nuclear plant 'hotspots' from 360-degree scan information.

Planar view of a piping facility.

Project readiness

The quantity of data that can be collected in one project from laser scanning should not be discounted. Archiving the millions or billions of points of data feasible from laser scanners secures the opportunity for immediate usability in the future. Having this amount of data at the ready for future projects reduces field changes, resurveys and rework, thereby increasing productivity.

Accommodating scope change

Scope change is to be expected for most capital projects. Market demand changes and unforeseen conditions heave into view midway through projects, new sources of feedstock appear or old ones become less attractive, or innovation inconveniently appears. Excellence in managing change is a hallmark of high performing project managers. Accurate, complete 3D and credible 3D data provides project managers with more flexibility and more options to deal with scope change. The solution space—the what-if scenarios--can be explored more quickly, thoroughly and with greater confidence with better 3D information.

Why isn't everyone doing this on every project?

Where is the catch? Why aren't all industrial plant projects executed with 3D scanning?

Here are some of the constraints:

- Lack of awareness. The worldwide population of working 3D laser scanners numbers fewer than 5,000 units. Though the market has grown 25-30% over the past five years and continues to expand, even through the teeth of a recession, it is still early in the adoption cycle.
- Perceived cost. For some projects, traditional methods are more cost effective. The challenge is to understand when it makes sense to make the leap.
- Inertia of old ways. Changing work flows is often painful. To get full value for laser scanning, organizations often need to embrace 3D and abandon familiar 2D processes.
- Integration challenges. While some of today's plant design solutions have embraced point cloud integration, notably products from AVEVA, Bentley, COADE and Intergraph, many have yet to do so.

None of these challenges is insurmountable; the enhanced productivity already delivered to thousands of industrial plant capital projects worldwide testifies to the compelling value proposition of today's 3D scanning-based workflows.

3D Laser Scanning in chemical facility

Methodology

This paper was written by Lieca N. Hohner, chief editor, and Tom Greaves, CEO, Spar Point Research LLC, Danvers, Massachusetts, and was commissioned by Faro Technologies, Inc. The results reported in this paper are based on telephone interviews conducted in late 2008 and early 2009 with managers at asset owner companies, engineering/construction firms and 3D laser scanning service providers as well as material drawn from Spar Point's research archives and industry conferences.

About Spar Point Research LLC

Founded in 2003, Spar Point Research LLC investigates and reports on 3D scanning, imaging and position capture technologies used to improve the productivity, quality, safety and risk profile of engineering, fabrication, construction and manufacturing operations. The company publishes SparView, an e-newsletter on business and technology trends, received by a growing list of more than 12,000 readers across multiple market segments. The company's annual SPAR conferences in the United States and Japan attract project managers, engineering and technical leads, industrial metrologists and surveyors. The events showcase 3D laser scanning, dynamic survey/LiDAR, new data capture and processing technologies used for 3D surveying and dimensional control for work on offshore platforms, nuclear power plant modifications, refinery revamps, discrete and process manufacturing, transportation, building and civil infrastructure projects, historic preservation as well as forensic investigations and security planning.

About the Authors

Tom Greaves, CEO, Spar Point Research LLC

Greaves has more than 20 years' experience in engineering, product development, and business research and analysis. He has authored reports on best practices for deploying 3D laser scanning, the benefits and paybacks of 3D plant design, MCAD distribution strategies and other issues, and has advised executives from engineering/procurement/construction firms and manufacturing companies on the application of information technology to solve business problems. Greaves has also advised the world's leading software developers and hardware suppliers on marketing, pricing, partnering, promotion and distribution strategies in North America, Europe and Japan.

Greaves' previous positions include analyst and marketing executive at Daratech, Inc. in Cambridge, Mass., product manager at Wexxar Packaging in Vancouver, Canada, and wireline engineer for Schlumberger Overseas S.A. in Abu Dhabi, Kuwait and Oman. He holds a B.Sc. in physics from Queen's University at Kingston, a M.Sc. in physics from the University of British Columbia, and a master's from the Sloan School of Management at the Massachusetts Institute of Technology. Greaves serves as a board member for the New England Suzuki Institute, membership secretary for the ASTM E57 Committee on 3D Imaging Systems and, until recently, assistant treasurer for the International Association of Forensic and Security Metrology.

Lieca N. Hohner, Chief Editor

Hohner edits and produces SparView, Spar Point's biweekly electronic newsletter serving readers in engineering, construction and manufacturing with information about the business and technology of 3D imaging. She has more than 10 years' experience in editing roles with national trade publications, most recently POB Magazine and their accompanying products, and helped launch a site preparation construction publication with a focus on new and evolving technology. Additionally, Hohner has experience in public relations, and special events marketing and consulting. She holds a bachelor's degree in journalism from Wayne State University.