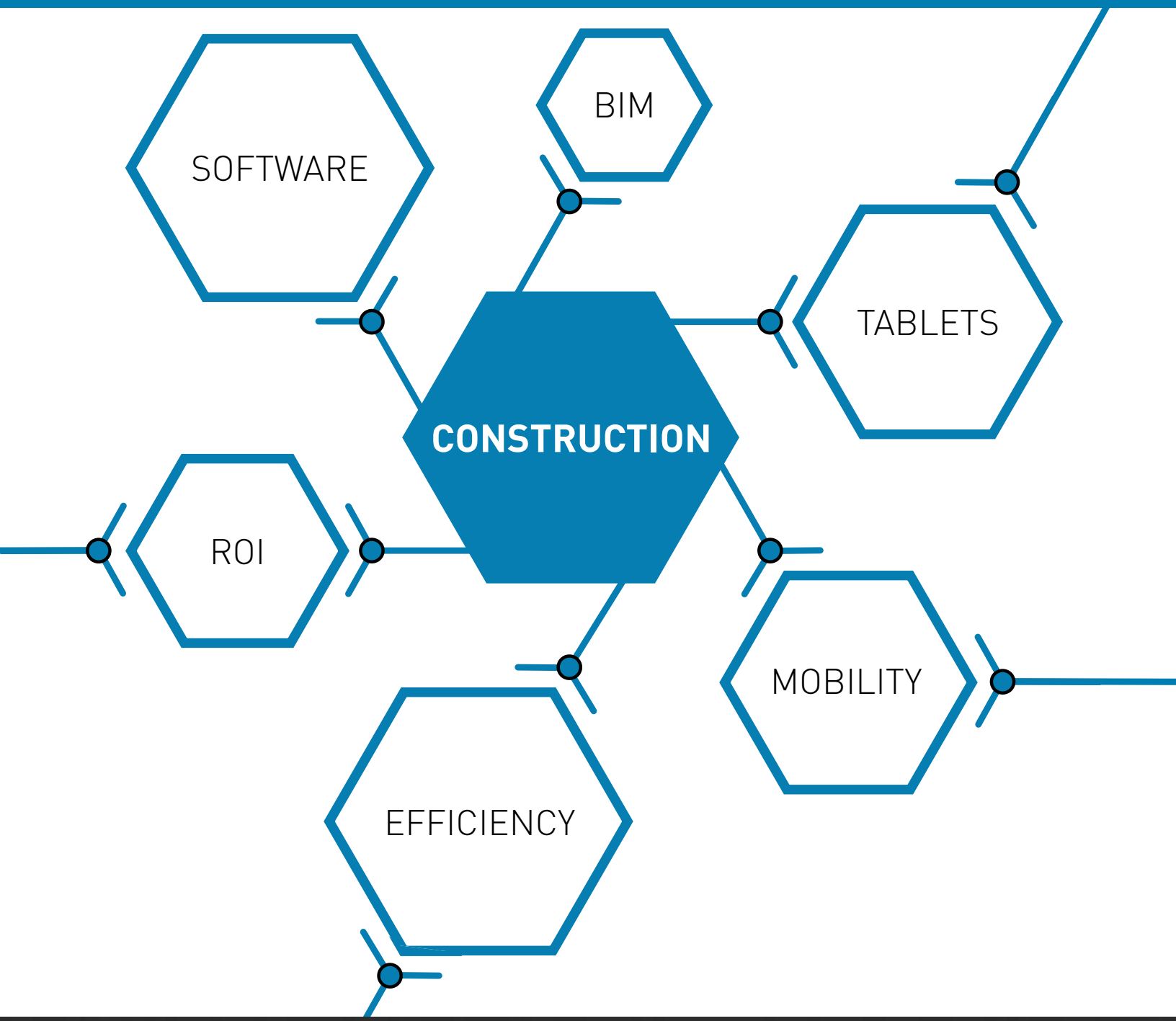
BUILDING THE FUTURE

CONNECTED CONSTRUCTION



PREAMBLE

Emerging technologies are driving a new era of construction. Mobility, in particular, is transforming the way the architecture; engineering and construction (A/E/C) firms work and the right mobile technologies are integral to market success. Leading construction companies are strategically utilizing mobile technologies with a focus on how jobsite workflows improve by enabling more collaboration, processing, and reporting capabilities to be conducted anywhere, anytime. Barriers between the office and the field are becoming non-existent and the move to flexible field devices and 24/7 connectivity is becoming the new normal in the construction industry.

Mobility translates to efficiency, productivity, and cost savings. Rugged tablet PCs are leading the way in the digital computing revolution and are becoming the field service hardware of choice. Portable and powerful computing solutions, when paired with advanced applications like BIM software or inspection and project tracking tools, provide A/E/C professionals the unparalleled advantage of "always on" mobility, power and collaboration. The delivery of real-time data, 3D drawings and documentation capabilities, and sophisticated voice and handwriting recognition is just the beginning of the transformation in construction. Building the future of construction – or "Connected Construction" – is being realized through the optimization of people, processes, and systems. The following report highlights current trends and innovations that are driving the new era of construction.

TABLET HISTORY

THE MOVE TO MOBILITY

The development of and demand for slate tablet devices re-emerged globally in the early 2000s, driven mostly by a need for a field-based tool with the power of a desktop PC and the flexibility and mobility of a handheld device.

David Krebs, senior analyst for VDC Research Group, an independent technology market research and consulting firm, confirms, "The market for slate tablets is now growing, particularly in niche markets that need more powerful modular and detachable solutions," notes Krebs. "The architecture, engineering and construction industry is one of the leading adopters along with healthcare, field service and the military sectors."

In fact, according to VDC Research, the evaluation and shift to mobile form factors is projected to double in growth from 2011 and 2014. VDC defines rugged mobile computers as devices that have been designed to withstand harsh environmental conditions including exposure to water, extreme temperatures, humidity and altitude, and drops from at least 4 feet. Additionally, these devices conform to MIL-STD 810F or 810G.

During this same time-period, slate tablets have expanded in terms of speed, features, and functionality. Today's systems incorporate Wi-Fi and mobile broadband, dual and longer life batteries, indoor and outdoor optimized displays, digital cameras, RFID and optional barcode scanners, smart card and biometric fingerprint readers, GPS, and high-fidelity voice and sound input devices. Rugged tablets also incorporate a solid-state hard drive and combined accelerometer designed to detect drops and shocks in order to reduce the possibility of data loss.

Along with hardware advances, field-optimized software for tablet PCs uniquely suited to the AEC market also continues to emerge. Industry specific software has become very specialized with companies like Bluebeam Software developing solutions that help users create, view, markup and edit PDFs of drawings and other documents while in the field. Additionally, LATISTA (now part of the Textura® Corporation) develops mobile software to support quality and material management, create punchlists, project commissioning and safety as well as building information modeling in the field. These firms are featured in the case studies that follow, in collaboration with Motion Computing.

CASE STUDY

MOTION AND BLUEBEAM SOFTWARE: A DIGITAL VOICE IN THE FIELD

The almost $500 million Terranea oceanfront resort is a 102-acre property situated along the southern California coastline in Rancho Palos Verdes. This property, managed by Destination Hotels and built by Turner Construction, features a 360-room hotel with 30 suites, 20 bungalows, 50 ocean view casitas and 32 villas. It also includes 135,000 square feet of indoor meeting and event space, a 25,000-square-foot destination spa, three swimming pools, three restaurants and a Todd Eckenrode-designed par three golf course.

With just six months to go on the project, the owner called for the project architects to gather base drawings for the hotel and ancillary buildings, and then begin the punch review process on the job site by recording punch items on these drawings. As is customary, the goal was to verify quality and completeness.

Erica Lee, an architect on the project, recalls, "The sheer magnitude of a hospitality job of this size and caliber was daunting. Not only were timeliness and accuracy imperative, I knew I also needed a mobile solution so I could maneuver about the entire site without sacrificing access to the vast library of drawings and specifications required to record information clearly and concisely."

Lee selected Motion Computing's rugged J-Series Tablet PC equipped with Bluebeam® Revu®, a tablet PC compatible PDF editor designed for the construction industry. Bluebeam allows users to quickly convert CAD files and other documents to PDF and edit PDFs with industry-standard markup tools.

For the Terranea resort project, Lee stored PDF copies of the entire set of design documents and specifications on the tablet hard drive. To automate the punch documentation process, she used Bluebeam to create PDF templates, such as hotel room floor plans, and custom punch symbols that were saved in Bluebeam's exclusive Tool Chest. This feature allowed Lee to select a symbol and place it on the PDF easily with the use of the tablet pen.

"Bluebeam's PDF editing solution provided all the tools needed for punch, and its tablet PC compatibility made it possible to complete the job digitally," adds Lee. "Along with Bluebeam, I needed a light, yet rugged tablet PC. The J-Series mobile technology was rugged enough to survive the bumps and jolts common on a jobsite, yet light enough to hang off my shoulder for an entire day with an indoor/outdoor screen for visibility throughout. I could not have done this job in the time allowed without the combination of the PC and Bluebeam PDF Revu. The combination made the entire process very smooth." Lee promptly finished the punch process, and the completion rate on the first back check was 90 percent. As a result, the Terranea oceanfront resort opened on time.


NATIONALS PARK STADIUM
WASHINGTON, DC

Sasha Reed, Director of Account Services for Bluebeam, says, "Mobility is always an issue in the building and construction industry, as is the frequent time lag between the office and field. Until recently, large rolls of paper drawings were a common sight. We saw the tablet PC as an ideal vehicle to move digital drawings from the office to the field with clarity, ease and speed. Since first introducing tablet integration in 2006, using Revu with tablet PCs has only become more and more popular among our users." Since then, an increasing number of Bluebeam users, from architects to contractors, have begun to take advantage of Bluebeam PDF Revu on the tablet PC to translate traditional office activities to the field.

"The tablet PC will continue to change the face of the industry," predicts Reed. "With it, our users are able to create an office in any environment. There's no longer a divide between the team in the field and the office staff. Superintendents, in particular, are picking up the tool very quickly. They're technology savvy and are finding that tablet PCs give them a voice in the field."

CASE STUDY

MOTION AND LATISTA FIELD SOFTWARE: PURPOSE-BUILT SOLUTIONS

Clark Construction Group, LLC, the 12th largest general contracting firm in the United States according to ENR magazine, took a significant step forward in automating its field operations management and quality programs by standardizing company wide on Motion Tablet PCs and LATISTA Field software. The combined hardware and software solution incorporates Clark employees, capital project owners, architecture and engineering firms, and subcontractors. Clark has deployed functional modules for punch list inspections, QA/QC, safety, BIM field integration, production/materials tracking, and commissioning.

The agreement was prompted by the company's initial implementation of tablet PCs and LATISTA Field on several projects, which produced significant results, including improved profitability and quality control for the company. Dave Golden, Clark CIO, commented: "We made the decision to roll out LATISTA Field company wide because LATISTA has proven to us that their field automation solutions improve operational efficiencies and collaboration between project stakeholders."

Clark and joint venture partners Hunt Construction Group and Smoot Construction completed Nationals Park stadium in Washington, D.C. in 23 months rather than the average 36 months for a sports venue that

size. The project team used LATISTA Field on Motion Tablet PCs to identify, record, communicate, and resolve more than 10,000 deficiency issues on the project. The software's automated time-stamps and documentation features which the Motion tablets enabled also helped Clark collaborate with Nationals Park's owners. "Having the data available in LATISTA Field was much better than the old fashioned way, which might take days or weeks," said Clark Project Executive Matt Haas about the project.

Thirty-five LATISTA software end-users used 20 Motion Tablet PCs on the stadium jobsite. Project owners and more than 100 subcontractors were then able to access field information from a web portal and through emailed reports.

Matt Haas, project executive for Clark on Nationals Park, concluded, "I'm surprised tablet PCs have taken so long to get to the industry. The computers always worked and were ready to go. I definitely think this is the way to go as tablet PCs get smaller, lighter, and more durable."

In San Diego, Calif., Clark turned over a $260 million U.S. Navy apartment complex called Pacific Beacon 60 days early with zero deficiencies. Clark used LATISTA Field and Motion Tablet PCs on the jobsite to automate quality assurance and control (QA/QC) inspections so that deficiency issues could be resolved earlier in the construction process, before rework was necessary. Owner representatives often participated in the inspections with Clark and could sign their approval in the field on the Motion Tablet PCs.

"Our old system took three times as long, since we were recording issues in the field on paper transcribing them, and setting them in a report," said Clark Project Engineer Scott Widmann, acknowledging the tablets' role in helping eliminate paper from the jobsite. "The LATISTA engine is immensely powerful; with it, we could manage our schedule better and keep the project moving."

Additionally, Clark and joint venture partner Balfour Beatty Construction used LATISTA Field and over 20 Motion Tablet PCs to automate QA/QC inspections and reports with the U.S. Army Corps of Engineers (USACE) on the $1.77 billion New Campus East (NCE) project for the National Geospatial-Intelligence Agency (NGA). Mobility is critical on the 98-acre jobsite, and the combined hardware and software solution allows users to perform inspections without the use of clipboard and paper drawings to access critical construction information, and to send and receive requests for information without returning to the construction office.

The chronological record of construction created in the LATISTA database is critical to the software implementation's success on the project. Being able to record and update daily reports and time stamped QA/QC logs and punch lists in LATISTA Field helped USACE track the project team's performance to ensure that construction was carried out with specified quality and minimum waste.

Chris Ramsey, executive vice president for LATISTA, said, "New technologies such as Motion's field-ready tablet PCs and 24/7 connectivity to web-based applications are replacing pen and paper processes at a rapid pace. As the tools for jobsite automation improve, more project managers, project executives, and owners hear success stories and want the same benefits for their project. A lot of the demand for LATISTA Field software is tied to the capabilities of the Motion Tablet PCs—technology that we strongly encourage the use of."

"In practice, individual project engineers and executives drive the use of the software," said Ramsey. "A particularly quality-conscious manager might insist on conducting QA/QC 'rolling punchlists' daily throughout construction and managing turnover using LATISTA Field and the tablet PCs to coordinate inspection times and communicate issues to subcontractors. Owner requirements might impel a contractor to automate materials tracking or production tracking. Safety professionals have insisted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AUSTIN, TX

on having issues documented with before-and-after photos to show that potential hazards have been corrected, to everyone's benefit." LATISTA's mobile automation solutions are designed to make the jobs of every project stakeholder easier, from owners to subcontractors.

GOING FORWARD

According to VDC Research's Krebs in the latest Construction Research Note, Mobile & Wireless Solutions in Construction , investments in mobile & wireless solutions have provided real and measurable benefits for construction operations, including:

- Improvements in worker productivity: 30.1%
- Reduced operating costs: 14.1%
- Increased sales/revenues: 13.6%

"Connected Construction" presents unprecedented opportunities for construction organizations to leverage new technologies, including mobile and rugged tablet PCs and tailored software applications, to improve operational performance. Look for increasing business value and TCO as purpose-built tablet PC devices and best in class software applications optimize people, processes, and systems to build the future of construction.

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CASE STUDY

SPAWGLASS IMPLEMENTS TABLET PCS: DRIVES BIM-ENABLED CONSTRUCTION

SpawGlass, a general contractor, construction manager, design/builder and civil contractor, began construction on the first phase of the Student Activity Center/Liberal Arts Building on the University of Texas (UT) campus in Austin, Texas several years ago.

Completed ahead of schedule, the first phase of the project included a 109,000-square-foot Student Activity Center with several theatres, conference rooms, a food court, dining rooms, organization areas, offices, student lounges, and entertainment venues. The upper two floors total 40,000 square feet and house offices, conference rooms, study facilities and labs for the College of Liberal Arts. The building has an additional 46,000 square feet of landscaped courtyards and roof terraces. Phase two of the project, the 200,000 square foot UT Liberal Arts Building houses classrooms, labs, and office space for the College of Liberal Arts.

RAISING THE BAR ON BIM:

Upon construction of both phases of the UT Student Activity Center/Liberal Arts Building, many people might first marvel at the structure's environmentally sustainable features and functionality. However, SpawGlass noted that the structure's digital, mobile data management solution is an industry first for SpawGlass. For the first time, SpawGlass delivered

a current, digital building information model (BIM) and database that UT facility managers can use to maintain the structure throughout its lifecycle. Perhaps surprising to some, the foundation for this innovation began with a tablet PC.

IN SEARCH OF MOBILITY:

Over the past few years, SpawGlass came to realize that it needed to replace time-consuming, paper-based construction management processes with a digital mobility solution, built around mobile tablet PCs, to better coordinate and communicate jobsite activities. According to Chris Tisdel, BIM technologist at SpawGlass, "During construction, there has always been a need to communicate design intent to the field and as-built conditions back to the office. This is particularly true when dealing with 3D models in relation to actual construction developments."

In selecting the tablet PCs, the SpawGlass team required a device with a barcode scanner, security protection, GPS functionality, and a built-in camera with streaming video capability. After a technology assessment, SpawGlass selected the rugged Motion® F5-Series Tablet PC, designed specifically for field-based computing.

TEXAS-SIZED SAVINGS:

Part of SpawGlass' construction manager-at-risk role is to set survey control at the jobsite that contractors and specialty contractors use to locate foundation lines and anchor bolts, among other activities. For the second phase of the UT project, SpawGlass' field layout professionals took advantage of an innovative survey solution and utilized the F5-Series digital mobility solution to connect BIM with the field, increasing the ease, speed and accuracy of the job.

SpawGlass combined the F5 with Primavera P6 project management software, Navisworks Simulate design, simulation, and project review software and Carlson surveying equipment with a robotic total station solution.

"We've replaced the laptop, data collector and paper drawings with the Motion F5, which has increased our mobility and production while further driving the transfer of digital data from the office to the field and back again," said Mike Sanford, superintendent with SpawGlass.

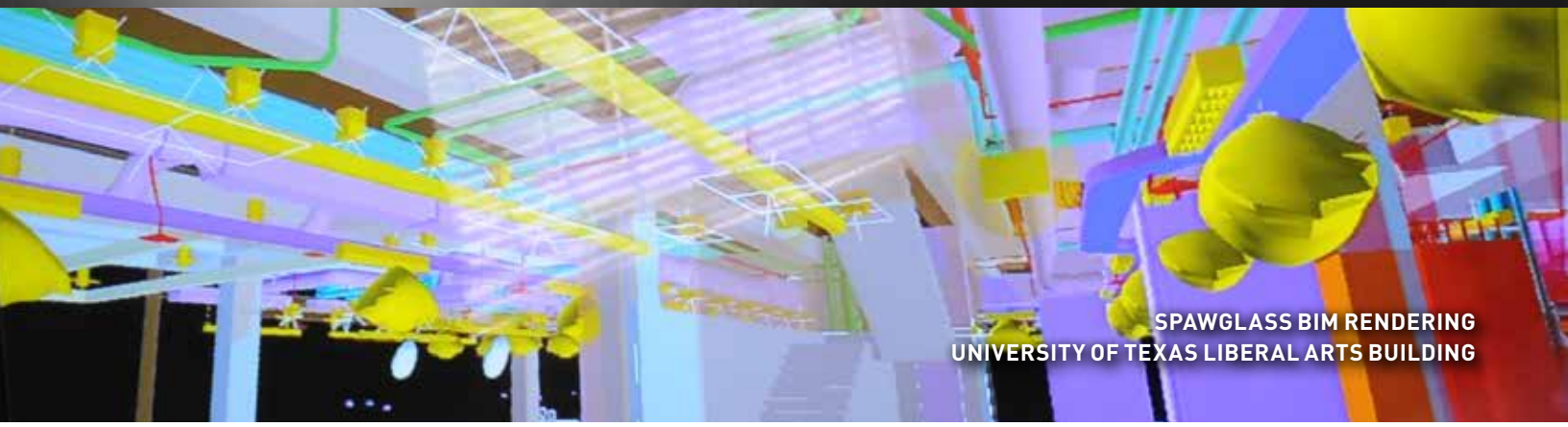
With the survey software loaded on the F5, SpawGlass was able to select control points directly from the CAD drawings or 3D model while in the field and manipulate, layer and overlay drawings on the fly.

"In past efforts, we've had data transfer issues between the data collector and the laptop, particularly when comparing shots of existing conditions to a BIM or CAD drawing," recalled Sanford. "With the F5-driven survey solution, there was no need to go back to the drawing board because the drawing board never leaves my side."

Built to integrate seamlessly into existing business IT infrastructures, the Motion F5 features an Intel® Core™ i5 or i7 vPro™ processor for superior performance, which can run virtually any application and, in many cases, replace laptops used in the office or in the field. The F5 also is available with the Intel® Core™ i3 processor for a lower starting price point and balance of power and battery life. For SpawGlass, the F5 significantly outperforms the 800 MHz data processors integrated within the robotic total station.

"The Motion F5 replaces the data collector and runs the robotic total station using Bluetooth® technology with almost no latency even when drawings are open in the program," said Sanford. "We can actually see where we are on the drawing and identify problems in real time, which was not previously possible on a standard-sized screen."

Sanford and his team also used the Motion F5 built-in Bluetooth® technology to download up-to-date drawings while in the field. With Navisworks Simulate software running on the F5, the team views in real time what is being installed as it relates to the finished product, therefore identifying and eliminating problems in the field before they become a cost impact. As questions arise, surveyors can show



SPAWGLASS BIM RENDERING
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specialty contractors 3D drawings of elevations as well as the finished product. Running the Primavera P6 Enterprise Project Portfolio Management scheduling program on the F5 makes it easy for surveyors to share the project schedule with field personnel in real time as well as input schedule updates while in the field.

"In the past, we've lost a significant amount of time going from the field table to the site and back again, responding to questions or issues that arise," said Sanford. "Keep in mind that the setup of a robotic total station takes about 30 minutes – and while we're gone, the specialty contractors are left waiting. Now, we never have to break down the survey system to check paper plans at the field table."

The F5-driven survey process also helped facilitate BIM data management. As the UT Liberal Arts Building Phase II portion of construction advanced, SpawGlass surveyors recorded actual field developments on the F5 and then instantly uploaded those changes.

"We take our office with us," concluded Sanford. "In short, the F5-driven survey solution has changed the world of field engineering, creating a more seamless, efficient process that pays dividends in the form of time, profit and deliverables, while easing frustrations in the field."

MODEL CONNECTIONS:

The first step in the construction management process was to create a detailed 3D model that incorporated the necessary geometry and design protocols, along with schedule, required materials, personnel and equipment resources and cost information. Once construction began, the models were converted to PDFs with links to requests for information (RFIs). On any project, regardless of size, RFIs are a common occurrence based on the way design and construction teams traditionally coordinate a project. Although the UT Student Activity Center/Liberal Arts Building is not an exception to the rule, the way SpawGlass interacts with RFIs and the design team is far more proactive and efficient than ever before.

For the first phase of construction, SpawGlass created thumbtack links of the rooms where there were design changes, marked RFIs on the digital drawings and exported the files to the F5.

"All the information – design data and RFIs – is at my fingertips," said Dan McClure, superintendent with SpawGlass. "Better yet, if a specialty contractor calls with questions, I simply look up the details on the F5. I never have to go back to the office trailer to review paper drawings or supplemental documents because those documents are always with me. There is no question that the F5 saves time and provides better jobsite coordination."

As changes or revisions occur in the field, superintendents use wireless connections on the F5 and jobsite data servers to funnel the information back

to the BIM team in the office, who revises the model accordingly. Some changes require the modification of objects within the model, while other changes require the modification of the data.

"All information passing through the tablet PC connection is captured digitally and can be incorporated into the BIM as data or as linked attachments," explained Tisdel. "The F5 streamlines jobsite activities, allowing users to not only augment the daily process, but moreover, reshape the process to drive efficiency."

INCORPORATING BIM:

Monitoring construction progress was just the first step in SpawGlass' technology evolution.

"What many people forget is that it's not the 3D geometric model that provides the greatest value to the owner – it's the data in the model," said Tisdel. "Whether the architect builds the model or we do, a model that is maintained throughout construction contains a huge amount of data that owners can use to manage the structure."

To make the most of BIM, owners must be able to share its data with proprietary facility management systems. To make this connection, these links must go beyond a model that is hyperlinked to a PDF or embedded with an image file as well as methods typically based on scanning, PDF transfers or digital printouts. Once something changes in the model, these digital documents become obsolete.

"Our ultimate goal is to deliver a current digital 3D model and database that property owners can use to manage the lifecycle of a structure and as a starting point for renovation or retrofit," explained Tisdel.

DATABASE CONNECTIONS:

The first step in creating the BIM/database connection is to map every object in the 3D model to a field in the database.

"The connection is bi-directional – if an object in the model changes, the database automatically changes as needed and vice versa. Therefore, no matter where the data is updated, the most current information is shown in both locations," said Tisdel.

Tisdel and his team then develop a connection between objects in the native 3D model and the corresponding, real objects in the structure. All connections are made with the ability to command and control over a wireless area network. These connections utilize existing protocols, such as BacNet, and project-specific controls software that relate each "intelligent" object, such as smart ballast lighting. SpawGlass relies on the Construction Operations Building Information Exchange (COBie) IFC-compliant format as a baseline for all of the facility's data that is gathered and pushed out to the connected database. "As the model evolves through design and construction, it will gradually incorporate additional data requested by the owner," said Tisdel.

Once the model hits critical mass and the data contained within is no longer created on a large scale, but rather simply revised, SpawGlass' 3D model will be exported to a purely data driven (no modeled objects), bi-directional database.

"The bi-directional database is primarily useful to the owner simply because most of the existing infrastructure that owners operate cannot directly connect to a BIM," added Tisdel. "The key is to have as few handoffs of information as possible between an owner's end product and the BIM."

At present, SpawGlass has developed a process where there is only one connection between any owner and the native BIM model deliverables – and the firm put the methodology to work on the UT Liberal Arts Building Phase II project.

OWNER'S EDGE:

During construction, all relevant information used to design, construct and coordinate the building process is readily accessible to anyone on the project team. To prepare the model for use by the owner, SpawGlass BIM experts tag building components with a barcode number within the model. SpawGlass barcoded major and minor MEP equipment for the UT Liberal Arts Building Phase II project.

By selecting an object's barcode, the owner or facility manager is able to view detailed information about each component. Each barcode includes all requested information, such as commissioning data, installation data, maintenance schedule, startup procedures and much more.

When construction is complete, SpawGlass downloads the model and database to the F5 for use in commissioning. At handover, the owner has a mobile deliverable that provides the level of coordination in the own and operate lifecycle stage that SpawGlass employed while constructing the project.

"The ability to hand the owner the F5s with all the commissioning data and the model that directly connects to their server system is very powerful," said Tisdel.

Once the database/model connection is "plugged in" to the owner's existing infrastructure, it then becomes the repository for all future information pertaining to that particular building.