Level Playing Field

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omeone in the Arizona Cardinals professional football organization has a new responsibility: removing the playing field from the stadium after each game and putting it back in before the next game.

Completed in time for the 2006 football season, the new Cardinals Stadium in Glendale, Arizona, is the first venue in the United States to feature a retractable playing field. The natural-turf playing surface will be inside the stadium only on game days. The rest of the time, the field will be outside the stadium, soaking up the Arizona sun and letting the grass grow until the next game. The rollout
The field is estimated to save $50 million in costs, since it is more economical to move the field than to retract the entire roof to allow the sunshine to reach the grass, and humidity problems inside the stadium are eliminated.

The stadium’s nominal seating capacity of 63,500 for the Cardinals’ National Football League (NFL) games is expandable up to 73,000 to host marquee games, such as the annual Tostitos Fiesta Bowls, the BCS Championship Bowl (in January, 2007) and the NFL’s Super Bowl XLII (in February, 2008).

Removing the field also provides unrestricted access to the stadium’s 152,000 ft² concrete floor, with its embedded utility grid, for events and staging. In this configuration, the stadium can accommodate numerous indoor events including trade shows, conventions, rodeos, concerts and other mega-events, such as the NCAA’s Final Four basketball championship game.

Designed by famed architect Peter Eisenman of New York-based Eisenman Architects in conjunction with construction architect HOK Sports, the stadium evokes the form of a barrel cactus and, from some aspects, a coiled snake; both images are true Southwestern icons.

Hunt Construction Group, the design builder for the three-year construction project, hired Project Design Consultants
(PDC) to perform all survey, heavy construction staking and quality control services. Headquartered in San Diego, California, PDC has grown to more than 200 employees since its founding in 1976 and provides planning, engineering and surveying services for construction and land development projects throughout southern California and Arizona.

Involved with the surveying activities for the stadium project since groundbreaking in early 2003, PDC’s Darren Yellowaga has performed virtually all surveying for the stadium construction. Today he is Project Surveyor and Crew Manager, directing two crews doing general site and parking lot surveying, as well as several other crews handling other local area projects for PDC.

The stadium’s large-scale design and sustainable building features required precise survey measurements and construction staking. Due to the high accuracies required (1/16th inch), Yellowaga used the Trimble 5600 Robotic Total Station for control, layout and as-builts of all aspects of the stadium. Trimble DiNi precision levels were used to bring in vertical control. A Trimble 3D scanner was also used for as-built surveys of the four super columns that support the roof. Surveying other aspects of the site (parking lots, picnic areas, etc.) was

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Home Is Where You Find it – or Build it

The Cardinals have played home games in a number of venues in their 100+ year history, but the new stadium is the first facility the team can truly call its own.

**1898**
Morgan Athletic Club began as a neighborhood group on Chicago’s South Side. Soon changed its playing site to Normal Field, and its name to the Chicago Normals.

**1901**
Owner Chris O’Brien bought used, faded maroon jerseys from the University of Chicago. The jerseys inspired O’Brien to say “That’s not maroon – it’s Cardinal red!” This prompted the team to be named the Racine Cardinals (Normal Field was on Racine Street).

**1906-1913**
Team disbanded.
done with two Trimble 5700 GPS rovers with a Trimble 4700 GPS base station. The Trimble Survey Controller software on the ACU Controllers allowed seamless integration of optical and GPS data. Quality-control data and real-time maps of what has been recorded or staked are stored for the entire project and can be viewed while in the field, eliminating additional field time. According to Yellowaga, the productivity gained through Integrated Surveying using optical and GPS survey equipment freed additional personnel to concentrate on other aspects of the project.

The rail system for the movable field involves almost 15,000 linear feet of rail (13 rails, each 1,146 feet in length).

Aerial view of the Cardinal Stadium with the field outside.

A view along the edge of the huge field tray in place in the stadium.

Racine Cardinals became one of 11 charter members of the American Professional Football League, forerunner of the National Football League (NFL).
The stadium occupies about 25 acres of a 165-acre site. The site also includes parking for 14,000 cars and numerous trees and lawn areas where fans can enjoy tailgate picnics. The stadium is aligned along a slight northwest to southeast axis to provide maximum sun exposure for the grass field and maximum shade for stadium patrons. Field level is 26’ below grade and 39’ below the main concourse level, which is set on 13’ berms.

“Using the 5600 robotic total station made the original control and staking go very quickly,” said Yellowaga. “You can do several foresights quickly and easily, then the machine takes over and automatically does all the backsights, measurements and angles. It takes any human error out of it. It’s a beautiful thing when you’re measuring rounds because it’s all automatic.”

Four main work points, essentially the four corners of the field, were initially marked with brass caps in concrete; these became radius points for the corners of the stadium, located at the intersection of the grid lines. The grid lines run parallel with the field to the corners, then radially to the corner workpoint.

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**Getting Control**

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completed. Yellowaga established main control at the bottom of the hole and set more control around the top of the hole.

“On the upper concourse, I would set up the 5600 robotic total station on the tripod stabilizer and do a resection off a minimum of three of the four points, check the fourth and do my layout on the upper concourse level,” said Yellowaga. “We set control lines all over that building for layout purposes, but having some kind of permanent control on each level was a little tough.”

Numerous expansion joints from 4” to 1’ wide are designed throughout the building. “The building is going to move,” he said. “So the base control had to be stable and something you could always go back to from whatever level of the stadium you’re on.”

Working on the Railroad
The huge steel and concrete “tray” that holds the playing field is 234 feet wide by 403 feet long and 3 feet high; it supports nearly 94,000 square feet (over two acres) of natural grass. The total field weight, including the dirt and sod, is nearly 17 million pounds. The tray rolls on 462 steel wheels, each riding on one of 13 parallel steel rails. The driving force is provided by 76 one-horsepower (1 hp) drive wheels that move the field 741 feet in to or out of the stadium in approximately one hour at a speed of 11.5 feet per minute.

The rail system for the movable field involves almost 15,000 linear feet of rail (13 rails, each 1,146 feet in length). The rails must be almost perfectly level to allow the small electric motors to move the field efficiently and dependably. The rails are mounted on concrete footings over a concrete slab using metal plates and clips that allow height adjustment. Once the correct height was verified, additional clips were welded on to hold the rail in position. Concrete was then
poured to completely surround the rails and the spaces between them to a depth of 1/8” below the tops of the rails.

Yellowaga did the footings layout; after the footings were in place, he laid out the rail clips. After the rails were installed, he made as-built shots every 9’9” along the rails (a total of 1,528 shots) to ensure the rails were correct to 1/16” in both elevation and sweep. (Sweep is left/right, rail to rail, between the 13 rails, to verify that they are all level relative to each other.) “When you’re trying to roll 17 million pounds with just 76 hp, the path better be absolutely flat,” he said. And it is; the field was moved into the stadium for the first time on June 1, 2006.

The Super Columns

The stadium roof includes two retractable panels centered over the field, allowing the stadium to be closed and air conditioned during the hot summer months and to remain open during the cooler seasons. The panels move along an arc, an engineering first, to create an opening of 240’ by 360’. These panels and the remaining non-retractable portion of the roof are covered in translucent Birdair fabric, which allows natural sunlight to penetrate and provides an open, airy feeling even while the roof is closed.

The roof is set on two giant Brunel trusses, each of which weighs 1,770 tons and is 87’ tall and 700’ long. The corner of each truss is set into a channel on each of the four super columns; each column is 173’ tall, 17.5’ wide and 12’ deep. The super columns had to be exactly vertical to enable the roof to be lifted and positioned on the tops, as well as to ensure they could carry the 22-million-lb weight of the finished roof.

Each segment, or lift, of the super columns was poured on site and raised into place. Yellowaga checked the dimensions of the forms for each segment to within 1/8”. “Getting each form exactly right means fewer problems later on,” he said. “We had the accuracies with the equipment and technology to get the forms just right, so we did.”

There were several different height increments: one from main concourse to club level, then from club level to suite level was a smaller pour, suites to upper level was another one, then there were four lifts above that as well. Yellowaga did an incremental as-built with the Trimble 5600 robotic total

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☐ No thanks, I’ll have a random collection of tools that don’t work well. And I’ll ride one of those giant-wheeled bicycles to the job site.
Station when each level was finished, using the instrument's direct reflex (DR) or reflectorless technology to allow data capture without the need for placing reflectors.

Confirming the as-built locations of the completed super columns was a critical task that required verification prior to lifting the central roof panels into place. A Trimble 3D scanner was used to quickly and accurately capture the existing location and shape of the super columns. The 3D scanner was placed in an optimum location and its position tied to the control network. The existing conditions were captured within a matter of minutes and the resulting point cloud was compared to the design drawings. Detail inspection tools gave the construction team the ability to map any deviations, within 1/8", between the structural engineers’ design and the contractors’ completed build. The 3D scanning provided a more efficient and far more comprehensive solution than employing traditional survey methods, allowing PDC to minimize any delays in the construction process.

In February of 2005, in the largest single lifting operation ever conducted in the U.S., the center portion of the roof was raised a total of 130’ over a four-day period. The weight lifted was 5,600 tons, equivalent to more than 36,000 football linemen.

Each end of each Brunel truss slid within a groove in a super column as it was lifted all the way up. Near the top of each column, a notch provides a mounting area for a steel plate. The roof was lifted above the notches, the steel plates installed, and the roof attached to them.

And since all the bolt patterns had to be laid out for drilling the steel plates and the tops of the super columns, up went Yellowaga with his robotic total station. “I was all harnessed up, safety lanyard, the whole bit,” he said “You overcome your fear of heights real quick on a project like this.”

This fall, when the Cardinals play in their new home, the fans will marvel at the beauty, comfort, and great visibility of the new stadium. The team owners and the Arizona Sports Authority believe it will be a success by all measures – including those made by Project Design Consultants.

G. Brian Parker is a technology writer living in Cupertino, California.